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CRC PROGRAM FOR QUANTIFYING PERFORMANCE OF KNOCK-SENSOR-EQUIPPED VEHICLES WITH VARYING OCTANE LEVEL

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COORDINATING RESEARCH COUNCIL, INC.
219 PERIMETER CENTER PARKWAY, ATLANTA, GEORGIA 30346

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COORDINATING RESEARCH COUNCIL
INCORPORATED
219 PERIMETER CENTER PARKWAY
ATLANTA, GEORGIA 30346
(404) 396-3400

CRC PROGRAM FOR QUANTIFYING PERFORMANCE OF KNOCK-SENSOR-EQUIPPED VEHICLES WITH VARYING OCTANE LEVEL

(CRC Project No. CM-124-86)

Prepared by the

Analysis Panel

of the

CRC Octane Technology and Test Procedures Group

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Automotive Vehicle Fuel, Lubricant, and Equipment Research Committee

of the

Coordinating Research Council, Inc.

ABSTRACT

A pilot study was conducted under the auspices of the Coordinating Research Council, Inc. (CRC) to assess the potential effects of gasoline octane quality on acceleration performance, fuel economy and driveability in vehicles equipped with electronic spark control systems (knock sensors). Fourteen vehicles were tested by five participating laboratories on CRC unleaded reference fuels of varying octane quality (78 to 104 RON). The test vehicles included nine naturally-aspirated and five turbocharged models. The results showed that acceleration performance was the parameter most sensitive to octane quality changes, particularly in the turbocharged models. No significant improvements in fuel economy were found with increasing octane. Driveability was not affected by fuel octane within the commercial fuel range, but three vehicles showed degraded driveability with sub-commercial octane fuels. Additional testing is planned within CRC to further quantify the effects of octane quality on acceleration performance in a wider variety of vehicles.

TABLE OF CONTENTS

TABLE OF CONTENTS - (Continued)

APPENDICES

I. INTRODUCTION

Modern gasoline engines marketed in the US are typically equipped with electronic control systems to continuously monitor various engine conditions and adjust certain control parameters such as fuel flow (air/fuel ratio), spark timing, and exhaust gas recirculation rates. Many of these systems employ knock sensors to detect engine knock. When engine knock is detected, the electronic control system retards the engine spark timing (and reduces boost pressure in certain turbocharged engines) to eliminate or reduce knock intensity. The adjustments to control engine knock, however, can potentially affect vehicle acceleration performance, fuel economy, and driveability. To investigate these potential effects, the Coordinating Research Council (CRC) Octane Technology and Test Procedures Group conducted a pilot study in which five laboratories tested fourteen knock-sensor-equipped vehicles to determine the impact of gasoline octane quality on acceleration performance, fuel economy, and driveability.

A list of participating laboratories and membership of the Data Analysis Panel are given in Appendices A and B, respectively.

II. SUMMARY AND CONCLUSIONS

Fourteen vehicles equipped with knock sensors were tested in a CRC pilot study to determine the effect of fuel octane quality on acceleration performance, fuel economy, and driveability. Nine vehicles were equipped with naturally-aspirated engines, and five were equipped with turbocharged engines. CRC FBRU reference fuels of varying octane quality were used for the tests. The results from the analyses are summarized as follows:

Acceleration Performance

- Most of the vehicles showed some improvement in acceleration performance at wide-open- and maximum-throttle (top-gear) conditions with large increases in octane quality over the wide octane range tested (about 80 to 100 RON). The turbocharged vehicles generally showed the largest effects.

- Within the current commercial octane range, premium octane-grade fuels showed no significant benefit compared to regular-grade fuels in the vehicles equipped with naturally-aspirated engines. However, premium-grade fuels did show distinct benefits compared to regular in most of the turbocharged vehicles, but premium fuels are recommended by the manufacturer for those vehicles.

- Performance was generally degraded at octane levels below the vehicle maximum octane requirement for borderline knock. Performance degradations were most pronounced in the turbocharged vehicles. Some vehicles showed improvements (1 to 10 percent) with fuel octanes higher than the maximum octane requirement.

Fuel Economy

- No significant improvements in fuel economy were found with increasing octane quality using the SAE J1082 test procedure. However, the acceleration rates prescribed in this method may not be severe enough to cause engine knock and ignition-timing retard and/or boost pressure reduction.

Driveability

- Three vehicles showed increased driveability demerits with low octane (less than 87 RON) quality fuels. No effect of fuel octane quality was found within the octane range of commercial fuels. The driveability degradations typically occurred at octane levels below the vehicle maximum octane requirement. Two vehicles showed small improvements (a reduction of 10 to 30 demerits) at octane levels above the maximum requirement.

III. TEST VEHICLES

The test vehicles are described in Table 1. The vehicles spanned the 1983 through 1988 model years, and included five turbocharged vehicles. Port-fuel-injected, throttle-body-injected, and carbureted fuel systems were represented. Twelve of the vehicles were equipped with automatic transmissions; two had manual transmissions. All vehicles had accumulated at least 6,000 miles, and all vehicles were adjusted to the vehicle manufacturer's specifications.

IV. TEST FUELS

The 1985/1986 and 1987/1988 CRC full-boiling range unleaded (FBRU) fuels, ranging from 79 through 104 RON, were used for the tests. Fuel properties of both series of fuels are detailed in Appendix C. All vehicles were tested on 87 through 100 RON. Eleven vehicles were tested with lower octane fuels (79 through 86 RON), and one vehicle was tested with a higher octane fuel (104 RON) to further quantify octane effects.

V. TEST PROGRAM AND DATA

The test program and test procedures used in this study are detailed in Appendix D. Testing was accomplished through determination of the octane number requirement, determination of acceleration performance, measurement of fuel economy, and rating of driveability. Actual test work deviated from the program write-up shown in Appendix D due to the length and the duration of the program.

Octane number requirements were determined for all vehicles using the CRC E-15 Technique. Acceleration performance tests were conducted at wide-open-throttle in all vehicles. Acceleration performance was also evaluated at maximum-throttle (top gear) conditions in five vehicles, and at part-throttle conditions in one vehicle. Fuel economy was evaluated in eight of the fourteen vehicles using the SAE J1082 Road Test Procedure. Driveability tests were conducted on eight of the vehicles using the CRC Cold-Start and Driveaway Procedure with the vehicle fully warmed-up. A matrix of tests conducted with each vehicle and the octane range investigated are shown in Table 2. Raw data are presented in Appendix E.

VI. DISCUSSION OF RESULTS

A. Octane Number Requirements

Vehicle octane number requirements were evaluated on the fourteen test vehicles using the CRC E-15-85 test procedure, and are shown in Table 3. Maximum octane number requirements using CRC FBRU fuels ranged from 84 to greater than 100 RON and occurred at maximum-throttle on all but one vehicle. Minimum octane number requirements were 0 to 15 RON lower than the maximum requirements of the twelve vehicles on which maximum octane numbers were determined.

B. Average Test Results

1. Acceleration Performance

The effect of fuel octane quality (FBRU RON) on acceleration performance is shown in Figures 1-9 for the naturally-aspirated (N/A) test vehicles and in Figures 10-16 for the turbocharged (T/C) test vehicles. The effect of octane quality changes on acceleration performance varied widely among the test vehicles. The largest effects were generally found in the turbocharged vehicles.

Over the wide range of octane quality evaluated (80 to 100 RON), most of the naturally-aspirated vehicles showed some gain in acceleration performance as octane quality was increased. Vehicles F and G showed little or no effect of octane on performance. In general, the performance versus octane quality trends were generally similar among the various parameters used to quantify acceleration performance.

The turbocharged vehicles showed more distinct acceleration performance gains as octane quality was increased over the wide octane range tested. Octane effects on performance were most pronounced in vehicles C and I. Vehicles B, J, and K showed somewhat lesser effects of octane. The effect of octane was statistically significant in all turbocharged vehicles over the full octane quality range tested. As found with the naturally-aspirated vehicles, the octane effects on performance were generally consistent among the various parameters used to quantify acceleration performance.

2. Fuel Economy

Average fuel economy results are shown in Figures 17-20 for the SAE J1082 Urban, Suburban, Interstate 55 mph, and Interstate 70 mph cycles. Linear regression analyses of all individual urban data showed directional fuel economy improvements with increasing octane quality in three of the eight vehicles; the other five vehicles showed directionally decreasing fuel economy with increasing octane. The effects were statistically significant (95 percent confidence level) in one vehicle which showed improved fuel economy with increasing octane and in one vehicle which showed poorer fuel economy with increasing octane. For the Interstate 55 mph cycle, six vehicles showed directional fuel economy losses with increasing octane; two showed fuel economy improvements. The effects were statistically significant in only one vehicle which showed directionally poorer fuel economy with increasing octane. The accelerations prescribed in the SAE J1082 cycles, however, may not be sufficiently severe to cause engine knock and spark retard.

3. Driveability

The effect of octane quality on warmed-up vehicle driveability is shown in Figure 21. Of the eight vehicles tested for driveability performance, five vehicles showed excellent driveability on all fuels tested and no effect of octane quality changes. Vehicles F, G, and H showed driveability degradations as octane was decreased below 87 to 91 RON. Degradations of Vehicle H were noticeably less than Vehicles F and G. Analysis of the detailed driveability results showed that the increased demerits at low octane levels were primarily attributable to trace surge malfunctions detected by the trained driver.

C. Effect of Fuel Octane Quality within the Regular to Premium Range

Table 4 shows the effects on acceleration, fuel economy, and driveability of operating with regular and premium fuels, and reports differences between these fuel levels. Differences that are statistically significant at the 95 percent confidence level are noted.

In addition to analyzing data across the entire octane range (79 to 104 RON), data for each parameter tested in each vehicle were also analyzed for effects within the octane range of fuels that are marketed commercially. For the purpose of this analysis, "regular" was defined as 90-91 RON and "premium" was defined as 97-100 RON. Data obtained with 90-91 RON fuels were averaged and coded "R" in Table 4, and data obtained with 97-100 RON were averaged and coded "P" in Table 4. For each parameter, percent change was calculated as [(P-R)/R]x100. In addition, vehicle data were grouped into two engine categories, turbocharged and naturally-aspirated. Vehicle owner's manuals recommended premium fuel for all the turbo charged engines and regular fuel for eight of the nine naturally-aspirated engines. These data on the effect of premium versus regular fuel are shown graphically in Figure 22.

From Table 4, it is apparent that the majority of the data is available for the four wide-open-throttle acceleration performance times and the four different fuel economy schedules. These data are plotted in Figure 1. The most obvious effect of using premium fuel relative to regular is a significant improvement in wide-open-throttle performance for the turbocharged vehicles, for which premium fuel is recommended by the manufacturer. The performance of naturally-aspirated vehicles was unaffected by using premium fuel compared with regular fuel.

There were no significant improvements in fuel economy for any of the vehicles when using premium fuel relative to regular fuel using the SAE J1082 procedure.

The driveability data in Table 4 and Figure 22 are limited, but all vehicles had relatively low demerit levels with either premium or regular fuels.

D. Effect of Octane Quality Relative to Vehicle Octane Requirement

1. Analysis Technique

The results from this study were analyzed to determine the effect of fuel octane quality on acceleration performance, fuel economy and driveability at octane levels higher and lower than the vehicle's maximum octane requirement. For consistent comparisons among the test vehicles, the average acceleration performance and fuel economy data for each test fuel were normalized relative to the test fuel with an octane number nearest the maximum vehicle E-15 octane requirement. The equations used to calculate the normalized values are shown below. Normalized values greater than 1.00 indicate improved acceleration performance or fuel economy relative to the vehicle octane number requirement; values less than 1.00 indicate poorer performance or fuel economy.

$$\text{Relative Fuel Economy} = \frac{\text{Miles Per Gallon (T.F.)}}{\text{Miles Per Gallc . (B.F.)}}$$

$$\text{Relative Acceleration Rate} = \frac{\text{(1/Time) (T.F.)}}{\text{(1/Time) (B.F.)}}$$

$$\text{Relative Speed} = \frac{\text{Miles Per Hour (T.F.)}}{\text{Miles Per Hour (B.F.)}}$$

$$\text{Relative Distance} = \frac{\text{Distance Covered (T.F.)}}{\text{Distance Covered (B.F.)}}$$

where TF = Test Fuel
BF = Base Fuel

The following table shows maximum and minimum octane requirements for each vehicle and the RON of the base fuel that was used for the basis of the normalization for each vehicle. The RON of the base fuel is generally within one octane number of the vehicle's maximum octane number requirement as measured by the E-15 test procedure.

Vehicle	Octane Req't Max	Octane Req't Min	Base Fuel RON	Octane Range Evaluated RON
A	85	82	84	80-97
B	96.5	96.5	97	87-100
C	98	98	97	87-100
D	92	92	91	87-100
E	84	83	83	83-100
F	86	85	87	83-100
G	92	91	91	83-100
H	90	88	91	82-97
I	>100	87	100	84-100
J	98	83	98	79-104
K	>100	86	100	84-100
L	97	85	97	83-99
M	95	84	95	81-98
N	96	84	96	82-98

2. Relative Acceleration Performance

The normalized acceleration performance results are shown in Figures 23 through 30 for the various wide-open-throttle tests and in Figure 31 for maximum-throttle (top gear) test conditions. The curves on the figures were developed using the results from all of the test vehicles. In general, the relative acceleration performance results showed similar trends among the various test speed ranges and throttle conditions.

Acceleration performance decreased in most vehicles as fuel octane quality was lowered below the vehicle maximum octane requirement. Performance degradations varied widely among the test vehicles. Vehicles with turbocharged engines generally showed greater performance losses than vehicles with naturally aspirated engines as octane was decreased below the maximum octane number requirement level. Vehicles C and I showed the largest performance losses.

At octane levels above the maximum vehicle octane number requirement, acceleration performance improved in some vehicles at certain test conditions. Average vehicle acceleration performance improvements were in the range of 1 to 5 percent at the various test conditions. Individual vehicles showed performance improvements of up to 10 percent at specific operating conditions. These performance increases at octane levels above the vehicle maximum octane requirement (as defined by the E-15 procedure) may be attributable to the knock control system or may occur because the current E-15 procedure does not encompass the vehicle acceleration conditions investigated in this study. (i.e., low-speed, wide-open-throttle conditions).

3. Relative Fuel Economy

The normalized fuel economy results are shown in Figures 32 through 35. The relative fuel economy of the test fuels varied widely, and no discernible trends were observed with fuel octanes above or below the vehicle maximum octane requirement. However, the acceleration rates encountered in the SAE J1082 test cycles, ranging from seven ft/sec^2 at low speeds to one ft/sec^2 at highway speed, may not be sufficient to cause engine knock. More severe test cycles may show an effect of octane on fuel economy.

4. Relative Driveability

The effect of octane quality on driveability demerits is shown in Figure 21 for the full range of octane levels tested. Five of the eight vehicles showed very good to excellent driveability on all test fuels and no effect of octane quality changes. Three vehicles showed driveability degradations (increased demerit levels) as octane was decreased below the commercial fuel range. Analysis of the detailed driveability results showed that the increased demerits at low octane levels were primarily attributable to trace surge and stumble malfunctions detected by the trained driver.

Similar to the analyses for acceleration performance and fuel economy described previously, the driveability demerits for the test fuels were adjusted relative to the driveability performance of the octane level fuel nearest the vehicle maximum octane requirement (base fuel). Driveability performance relative to vehicle octane requirement was calculated by subtracting the demerits of the test fuel from the demerits of the base fuel.

The results of this analysis are shown in Figure 36. Three of the eight vehicles showed degraded driveability performance as fuel octane was decreased by 4 to 8 RON below the vehicle octane requirement. Two vehicles showed driveability improvements as octane was increased above the maximum octane requirement. The improvements in these two vehicles ranged from about 10 to 30 demerits.

VII. RECOMMENDATIONS

Results from this pilot program have shown that acceleration performance can be improved in some vehicles when using a gasoline 5 RON above the maximum octane requirement of the vehicle. Time reductions of about 4 percent were observed during full-throttle accelerations.

An additional program running a fewer variety of tests on more vehicles is recommended. Knock-sensor vehicles are preferred, but data on non-knock-sensor-equipped vehicles are encouraged so data can be developed on this population also. The program would involve wide-open-throttle (WOT) accelerations from 0 to 70 mph, picking off times at 30, 60, and 70 mph. The maximum throttle octane requirement fuel in the FBRU series would be used along with fuels 4 RON lower, and 4 and 8 RON higher. In addition, detent accelerations in top gear from 40 to 60 mph would be measured on the same four fuels. Changes in acceleration times would be compared to the base fuel (octane requirement of the vehicle).

TABLES AND FIGURES

TABLE 1

TEST CARS

Year	Make/Model	Engine Disp.,L	Engine Type (1)	Trans.	Fuel System	Knock Control System (2)	Mfr. Fuel Recomm. (3)
1983	Buick Regal	3.8	V-6T	A-4	4V	S	P
1984	Buick Regal	3.8	V-6T	A-4	PFI	SB	P
1984	Ford Thunderbird	2.3	L-4T	A-3	TBI	S	P
1985	Chevrolet Impala	4.3	V-6	A-3	TBI	S	R
1985	Oldsmobile Calais	3.0	V-6	A-3	PFI	S	R
1985	Pontiac Sunbird	1.8	L-4T	A-3	PFI	SB	P
1985	Dodge Diplomat	5.2	V-8	A-3	2V	S	P
1985	AMC Alliance	1.7	L-4	A-3	TBI	IS	R
1985	VW Golf GTI	1.8	L-4	M-5	TBI	S	R
1987	Chrysler LeBaron	2.2	L-4T	A-3	PFI	ISB	P
1988	Buick Skylark	3.0	V-6	A-3	PFI	S	R
1988	Chevrolet Beretta	2.8	V-6	A-3	PFI	S	R
1988	Ford Taurus	3.0	V-6	A-3	PFI	IS	R
1988	Jeep Comanche	4.0	L-6	M-5	PFI	IS	R

(1) T = Turbocharged

(2) S = All-cylinder retard
IS = Individual-Cylinder Retard
SB = All-cylinder retard and boost control
ISB = Individual cylinder retard and boost control

(3) R = Regular Fuel
P = Premium Fuel

TABLE 2

Vehicle Tests Conducted

Test Vehicle	Octane Requirement	Acceleration Performance	Fuel Economy	Driveability	Evaluated Octane Range	
A	X	X	X	X	80	97
B	X	X	X	X	87	100
C	X	X	X	X	87	100
D	X	X	X	X	87	100
E	X	X	X	X	83	100
F	X	X	X	X	83	100
G	X	X	X	X	83	100
H	X	X	X	X	82	97
I	X	X			84	100
J	X	X			79	104
K	X	X			84	100
L	X	X			83	99
M	X	X			81	98
N	X	X			82	98

TABLE 3

Octane Number Requirements
CRC FBRU Reference Fuels

Vehicle	Maximum RON	Maximum MON	Maximum (R+M)/2	Maximum RPM	Maximum Gear	Minimum RON	Minimum MON	Minimum (R+M)/2	Minimum RPM	Minimum Gear	Fuel Series
A	85.0	79.0	82.0	1500	4	84.0	78.4	81.2	1400	4	85/86
B	96.5	86.0	91.2	4000	3	96.5	86.0	91.2	4000	3	87/88
C	98.0	86.9	92.4	3500	2	98.0	86.9	92.4	3500	2	87/88
D	92.0	82.9	87.4	1500	3	92.0	82.9	87.4	1500	3	87/88
E	84.0	78.4	81.2	1850	3	83.0	77.6	80.3	1850	3	85/86
F	86.0	79.6	82.8	1600	3	85.0	79.0	82.0	1850	3	85/86
G	92.0*	83.0	87.5	1500	3	91.0*	82.5	86.8	1475	3	85/86
H	90.0	81.9	86.0	2600	2	88.0	80.8	84.4	2400	2	85/86
I	>100.0	-	-	1800	4	87.0	79.7	83.4	1800	4	87/88
J	98.0	86.9	92.4	2700	3	83.0	77.0	80.0	2700	3	87/88
K	>100.0	-	-	3600	3	86.0	79.0	82.5	3600	3	87/88
L	97.0	86.3	91.6	2000	4	85.0	78.4	81.7	2000	4	87/88
M	95.0	84.9	90.0	2600	3	84.0	77.7	80.8	2600	3	87/88
N	96.0	85.6	90.8	2000	3	84.0	77.7	80.8	2000	3	87/88

* Octane requirement occurred at part-throttle.

TABLE 4

EFFECTS OF PREMIUM FUEL RELATIVE TO REGULAR FUEL

	TURBOCHARGED VEHICLES																			
	B				C				I				J				K+			
	R	P	▲	%	R	P	▲	%	R	P	▲	%	R	P	▲	%	R	P	▲	%
WOT ACCEL																				
0-30 MPH, SEC.	3.2	3.0	-0.2*	-6	3.9	3.0	-0.9*	-23	5.0	4.2	-0.8*	-16	4.3	4.2	-0.1	-2	5.2	4.8	-0.4	-8
0-50 MPH, SEC.	7.2	6.8	-0.4*	-6	10.1	6.6	-3.5*	-35	11.1	8.4	-2.7*	-25	8.4	8.3	-0.1*	-1	9.8	8.9	-0.9	-9
0-60 MPH, SEC.	10.4	9.6	-0.8*	-8	13.4	9.3	-4.1*	-31	14.3	11.3	-3.0*	-21	11.5	11.1	-0.4*	-3	13.2	11.7	-1.5	-11
40-60 MPH, SEC.	5.4	5.0	-0.4*	-7	7.4	4.6	-2.8*	-38	10.5	6.4	-4.1*	-39	6.3	6.2	-0.1*	-1	6.6	5.7	-0.9	-14
0-5 SEC., FT.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
0-5 SEC., MPH	41.0	43.2	+2.2*	+5	35.0	43.0	+8.0*	+23	-	-	-	-	-	-	-	-	-	-	-	-
1/4 MI., SEC.	-	-	-	-	-	-	-	-	21.9	18.7	-3.2*	-15	19.0	18.6	-0.4*	-2	20.0	19.3	-0.7	-4
1/4 MI., MPH	-	-	-	-	-	-	-	-	67.2	80.8	+13.6*	+20	76.0	78.3	+2.3*	+3	76.2	80.6	+4.4	+6
MAX. THROTTLE ACCEL.																				
40-60 MPH, SEC.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PT ACCEL.																				
10-60 MPH, SEC.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SAE FUEL ECONOMY																				
URBAN	21.6	20.7	-0.9	-4	15.9	15.1	-0.8	-5	-	-	-	-	-	-	-	-	-	-	-	-
SUBURBAN	28.5	27.2	-1.3	-5	19.4	20.4	+1.0	+5	-	-	-	-	-	-	-	-	-	-	-	-
INTERSTATE 55 MPH	30.3	28.8	-1.5	-5	24.2	25.2	+1.0	+4	-	-	-	-	-	-	-	-	-	-	-	-
INTERSTATE 70 MPH	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DRIVEABILITY																				
DEMERITS	0	0	0	0	0	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-

R = Data with Regular Fuel (90-91 RON)
P = Data with Premium Fuel (97-100 RON)
▲ = P-R
% = (▲/R) x 100
* = difference significant at 95% level
+ = Vehicle K results for regular fuel are an average of 86 and 93 RON fuels.

TABLE 4
Continued

EFFECTS OF PREMIUM FUEL RELATIVE TO REGULAR FUEL

	NATURALLY-ASPIRATED VEHICLES																			
	A				D				E				F				G			
	R	P	Δ	%	R	P	Δ	%	R	P	Δ	%	R	P	Δ	%	R	P	Δ	%
WOT ACCEL																				
0-30 MPH, SEC.	4.6	4.4	-0.2	-4	4.5	4.6	+0.1	+2	4.2	4.2	0	0	5.4	5.6	+0.2	+4	5.0	5.0	0	0
0-50 MPH, SEC.	9.4	9.4	0	0	9.0	9.0	0	0	8.8	8.7	-0.1	-1	10.1	10.2	+0.1*	+1	10.1	10.1	0	0
0-60 MPH, SEC.	12.5	12.4	-0.1	-1	12.6	12.7	+0.1	+1	12.1	12.2	+0.1	+1	13.8	14.0	+0.2*	+1	14.0	13.8	-0.2	-1
40-60 MPH, SEC.	7.3	7.6	+0.3	+4	7.3	7.1	-0.2	-3	6.0	6.1	+0.1	+2	6.2	6.3	+0.1	+2	6.9	6.7	-0.2	-3
0-5 SEC., FT.	130.8	134.8	+4.0	+3	126.2	126.4	+0.2	0	145.4	146.1	+0.7	0	117.8	115.9	-1.9	-2	122.4	120.2	-2.2	-2
0-5 SEC., MPH	-	-	-	-	32.4	34.4	+2.0	+6	34.2	34.4	+0.2	+1	28.0	27.6	-0.4	-1	30.2	29.8	-0.4	-1
1/4 MI., SEC.	19.2	19.2	0	0	19.1	19.1	0	0	-	-	-	-	-	-	-	-	-	-	-	-
1/4 MI., MPH	73.6	73.3	-0.3	0	75.2	75.0	-0.2	0	-	-	-	-	-	-	-	-	-	-	-	-
MAX. THROTTLE ACCEL.																				
40-60 MPH, SEC.	10.6	10.8	+0.2	+2	-	-	-	-	8.2	8.4	+0.2*	+2	14.6	15.1	+0.5	+3	11.8	11.9	+0.1*	+1
PT ACCEL.																				
10-60 MPH, SEC.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15.7	15.8	+0.1	+1
SAE FUEL ECONOMY																				
URBAN	22.9	22.4	-0.5	-2	18.7	18.7	0	0	-	18.0	-	-	17.0	16.7	-0.3	-2	-	15.7	-	-
SUBURBAN	32.8	31.8	-1.0	-3	29.2	29.4	+0.2	+1	-	31.6	-	-	23.4	23.1	-0.3	-1	-	22.9	-	-
INTERSTATE 55 MPH	38.6	35.3	-3.3*	-9	33.2	32.8	-0.4	-1	-	34.5	-	-	30.0	28.7	-1.3*	-4	-	26.3	-	-
INTERSTATE 70 MPH	-	-	-	-	27.9	27.9	0	0	-	30.7	-	-	23.4	21.0	-2.4*	-10	-	22.2	-	-
DRIVEABILITY																				
DEMERITS	1.0	0	-1.0	-100	7.0	8.0	+1.0	+14.0	-	20.0	-	-	10.0	10.0	0	0	-	17.0	-	-

R = Data with Regular Fuel (90-91 RON)
P = Data with Premium Fuel (97-100 RON)
Δ = P-R
% = (Δ/R) x 100
* = difference significant at 95% level

TABLE 4
Continued

EFFECTS OF PREMIUM FUEL RELATIVE TO REGULAR FUEL

	NATURALLY-ASPIRATED VEHICLES															
	H				L				M				N			
	R	P	Δ	%	R	P	Δ	%	R	P	Δ	%	R	P	Δ	%
WOT ACCEL																
0-30 MPH, SEC.	5.2	5.1	-0.1	-2	4.3	4.3	0	0	4.3	4.2	-0.1*	-2	4.4	4.4	0	0
0-50 MPH, SEC.	11.6	11.3	-0.3	-2	8.4	8.4	0	0	8.3	8.2	-0.1*	-1	9.4	9.3	-0.1*	-1
0-60 MPH, SEC.	16.2	16.1	-0.1	-1	11.0	10.9	-0.1*	-1	11.1	10.9	-0.2*	-2	12.0	12.0	0	0
40-60 MPH, SEC.	8.3	8.4	+0.1	+1	5.9	5.9	0	0	5.8	5.6	-0.2*	-4	5.3	5.3	0	0
0-5 SEC., FT.	118.0	119.0	+1.0	+1	-	-	-	-	-	-	-	-	-	-	-	-
0-5 SEC., MPH	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1/4 MI., SEC.	20.8	20.7	-0.1	0	18.1	17.9	-0.2*	-1	18.2	18.0	-0.2*	-1	21.3	21.1	-0.2*	-1
1/4 MI., MPH	67.9	68.1	+0.2	0	81.0	82.0	+1.0*	+1	78.5	80.0	+1.5*	+2	69.0	70.0	+1.0*	+1
MAX. THROTTLE ACCEL.																
40-60 MPH, SEC.	6.5	6.4	-0.1	-2	-	-	-	-	-	-	-	-	-	-	-	-
PT ACCEL.																
10-60 MPH, SEC.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SAE FUEL ECONOMY																
URBAN	23.0	22.9	-0.1	0	-	-	-	-	-	-	-	-	-	-	-	-
SUBURBAN	28.1	27.3	-0.8	-3	-	-	-	-	-	-	-	-	-	-	-	-
INTERSTATE 55 MPH	26.9	24.3	-2.6	-10	-	-	-	-	-	-	-	-	-	-	-	-
INTERSTATE 70 MPH	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DRIVEABILITY																
DEMERITS	2.0	0	-2.0	-100	-	-	-	-	-	-	-	-	-	-	-	-

R = Data with Regular Fuel (90-91 RON)
P = Data with Premium Fuel (97-100 RON)
Δ = P-R
% = (Δ/R) x 100
* = difference significant at 95% level

FIGURE 1

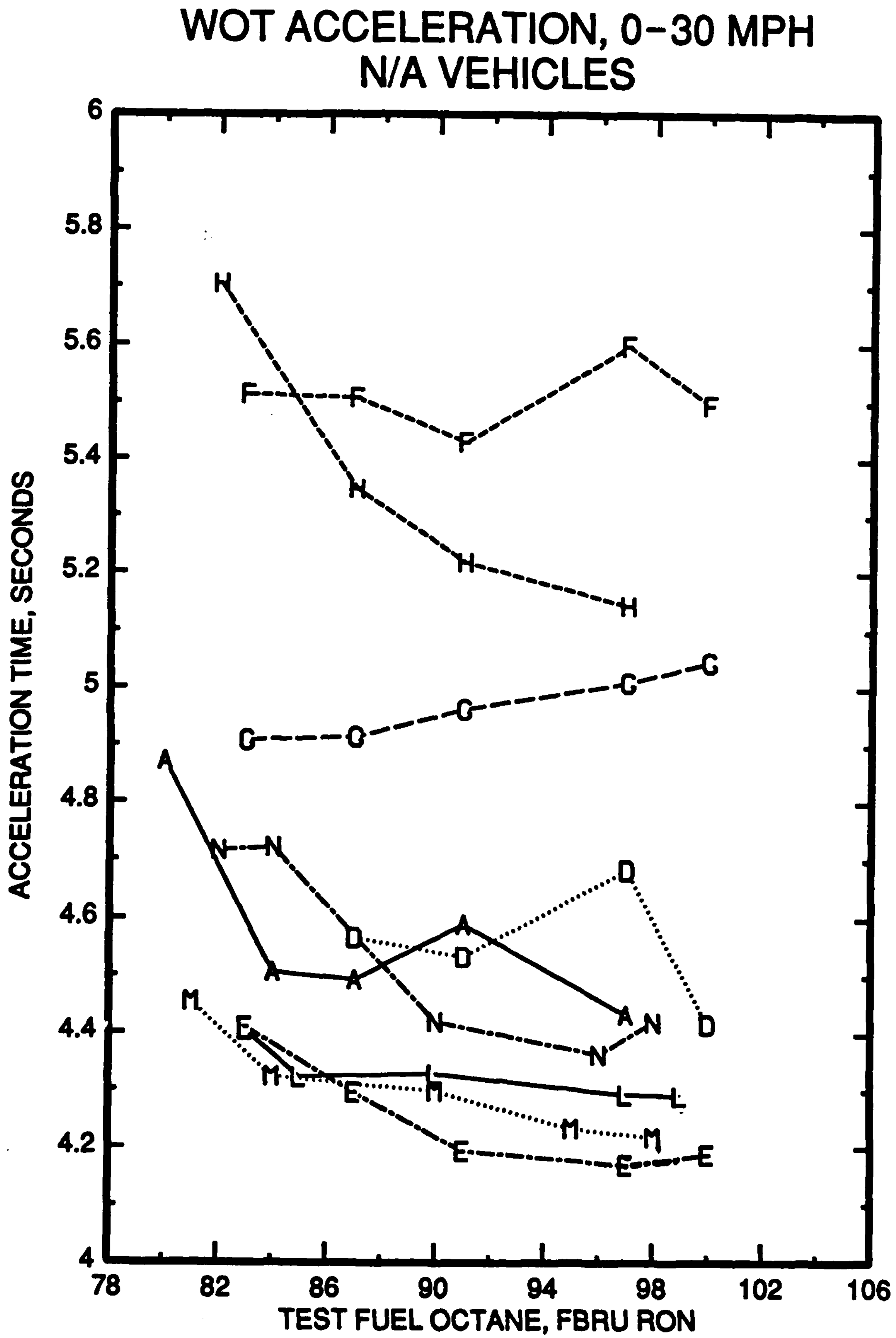

WOT ACCELERATION, 0-30 MPH
N/A VEHICLES
ACCELERATION TIME, SECONDS
TEST FUEL OCTANE, FBRU RON
6
5.8
5.6
5.4
5.2
5
4.8
4.6
4.4
4.2
4
78
82
86
90
94
98
102
106

FIGURE 2

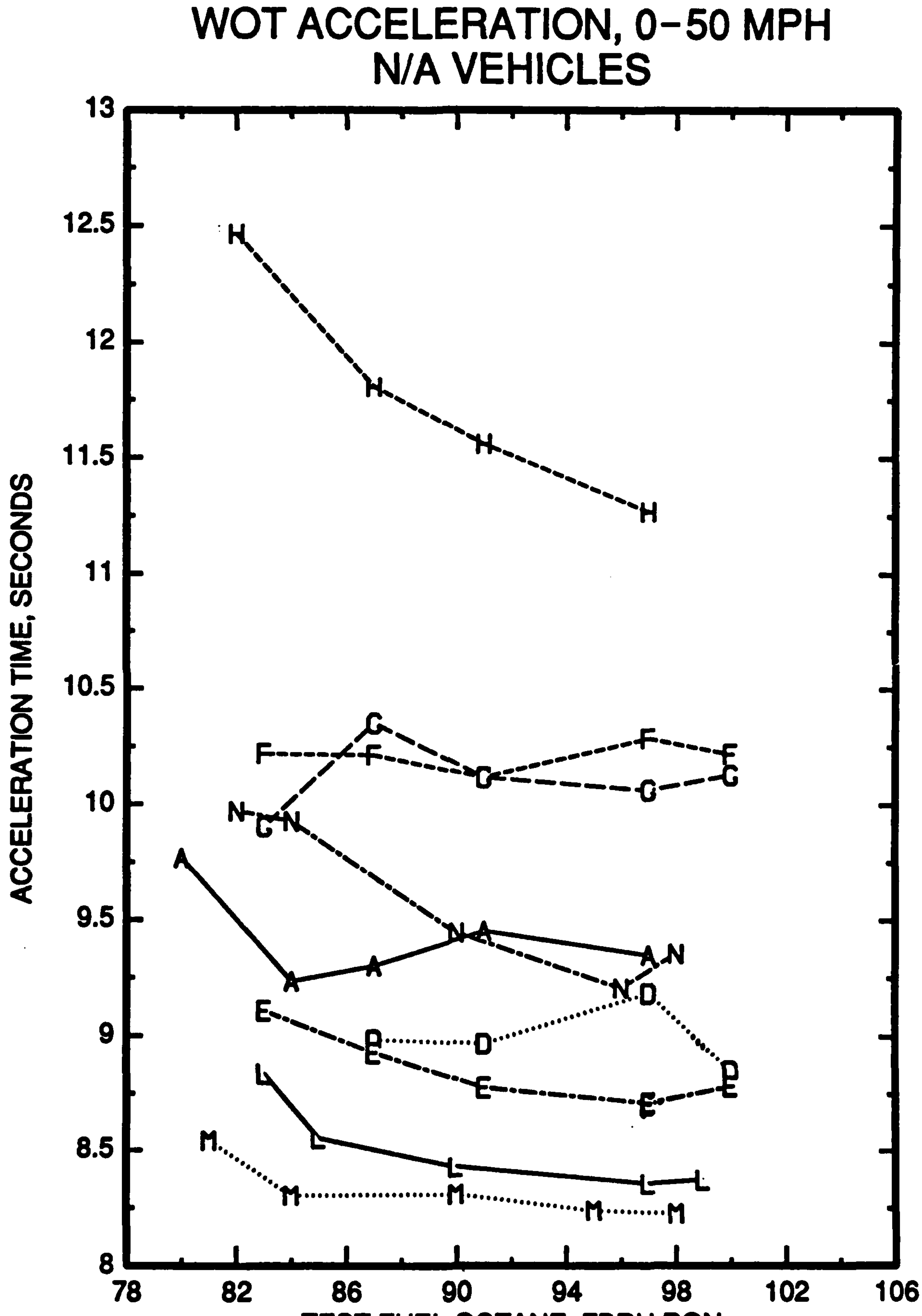

WOT ACCELERATION, 0-50 MPH
N/A VEHICLES
ACCELERATION TIME, SECONDS
TEST FUEL OCTANE, FBRU RON
13
12.5
12
11.5
11
10.5
10
9.5
9
8.5
8
78
82
86
90
94
98
102
106

FIGURE 3

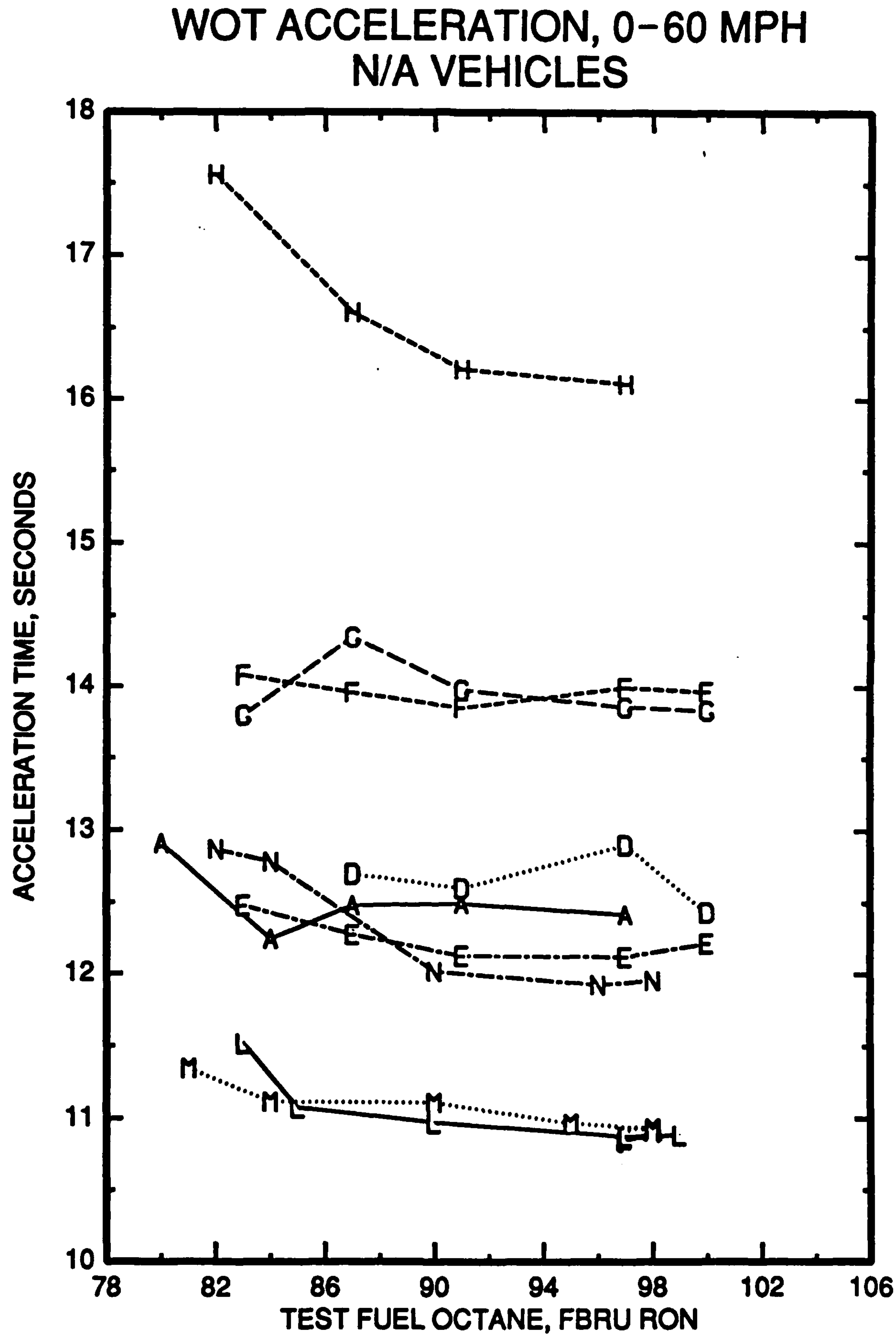

WOT ACCELERATION, 0-60 MPH
N/A VEHICLES
ACCELERATION TIME, SECONDS
TEST FUEL OCTANE, FBRU RON
18
17
16
15
14
13
12
11
10
78
82
86
90
94
98
102
106

FIGURE 4

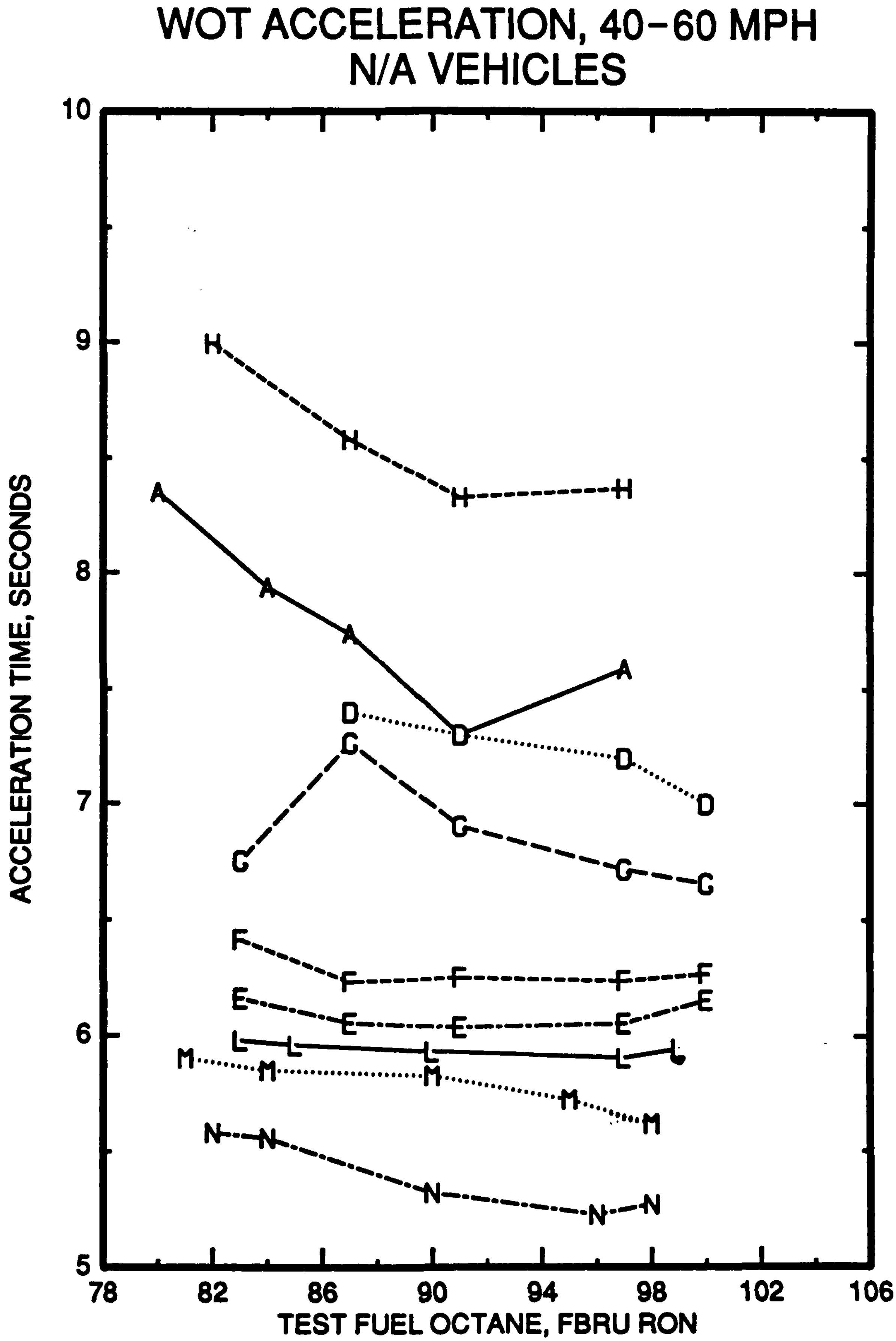

WOT ACCELERATION, 40-60 MPH
N/A VEHICLES
ACCELERATION TIME, SECONDS
TEST FUEL OCTANE, FBRU RON
10
9
8
7
6
5
78
82
86
90
94
98
102
106
H
A
D
C
F
E
L
M
N

FIGURE 5

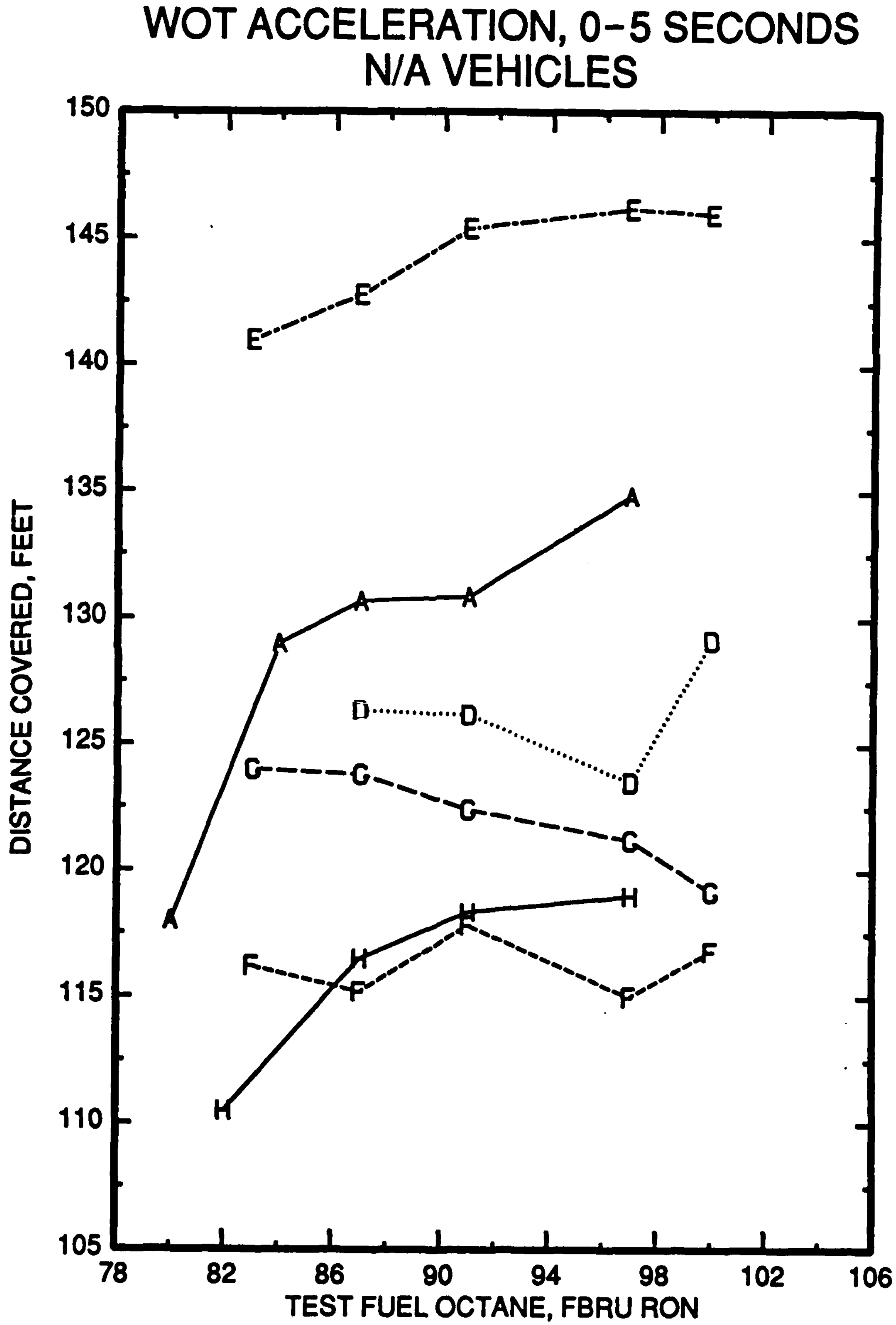

WOT ACCELERATION, 0-5 SECONDS
N/A VEHICLES
DISTANCE COVERED, FEET
TEST FUEL OCTANE, FBRU RON
150
145
140
135
130
125
120
115
110
105
78
82
86
90
94
98
102
106
E
A
D
C
H
F

FIGURE 6

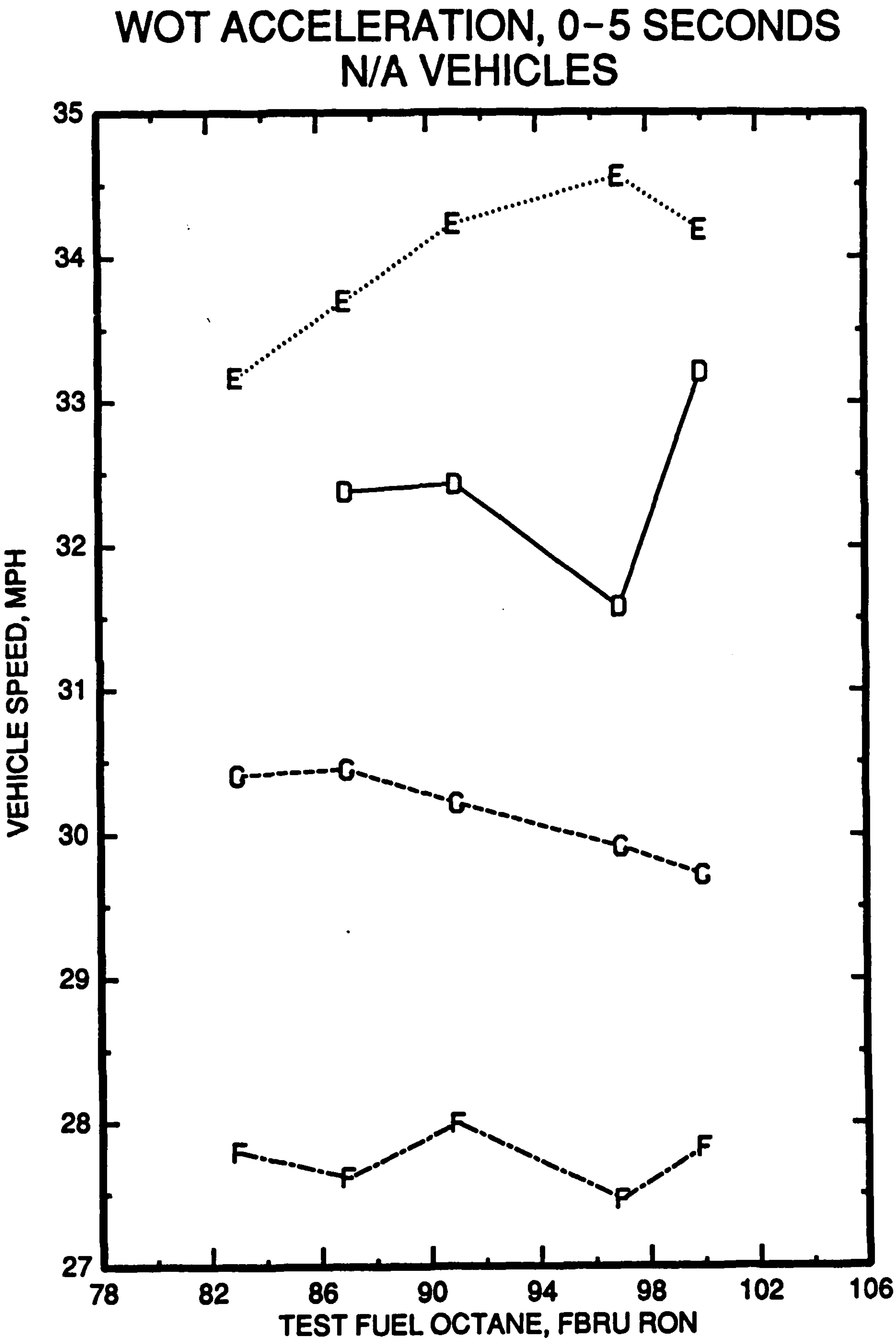

WOT ACCELERATION, 0-5 SECONDS
N/A VEHICLES
VEHICLE SPEED, MPH
TEST FUEL OCTANE, FBRU RON
35
34
33
32
31
30
29
28
27
78
82
86
90
94
98
102
106
E
D
G
F

FIGURE 7

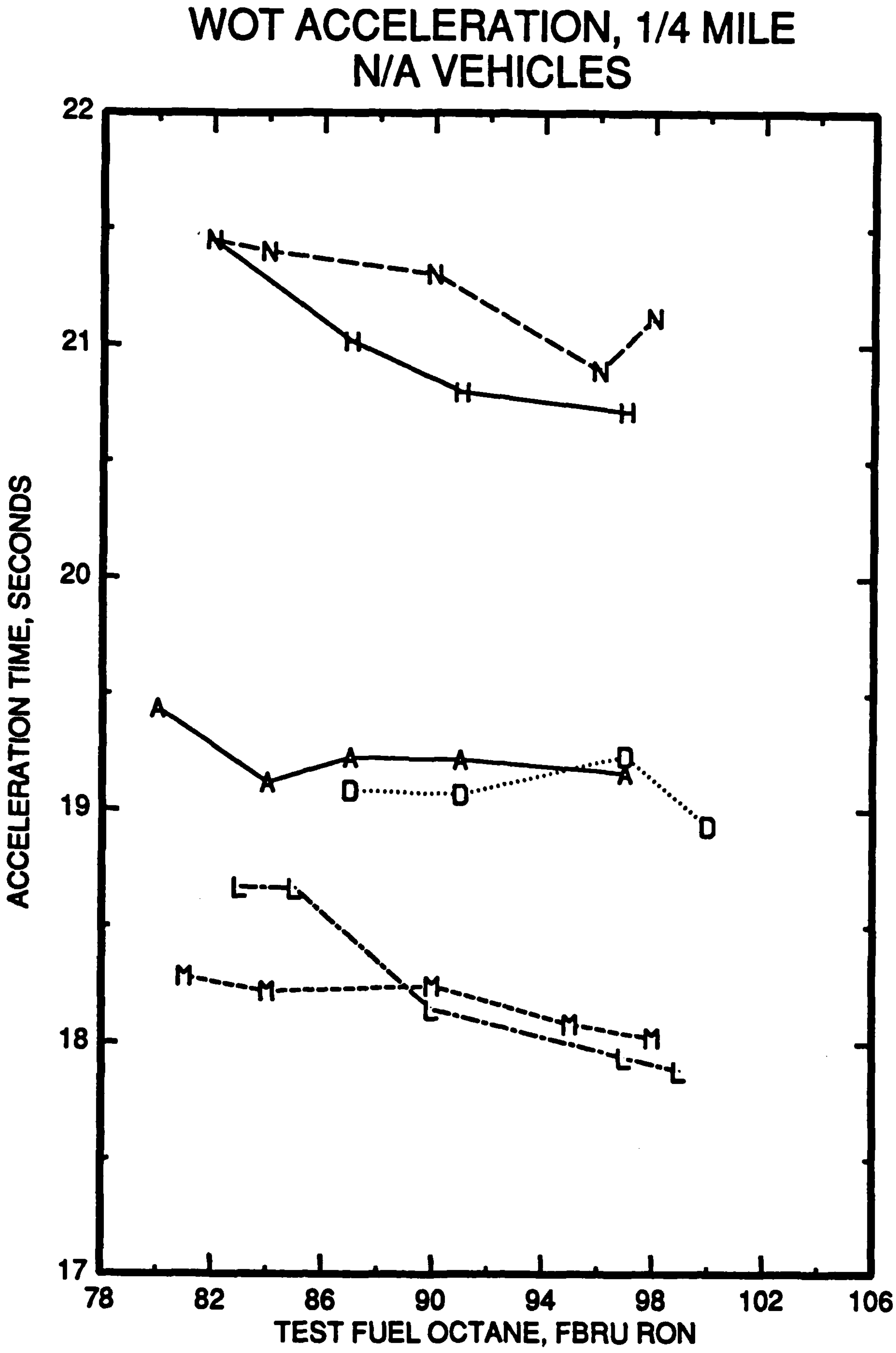

WOT ACCELERATION, 1/4 MILE
N/A VEHICLES
ACCELERATION TIME, SECONDS
TEST FUEL OCTANE, FBRU RON
22
21
20
19
18
17
78
82
86
90
94
98
102
106
N
H
A
D
L
M

FIGURE 8

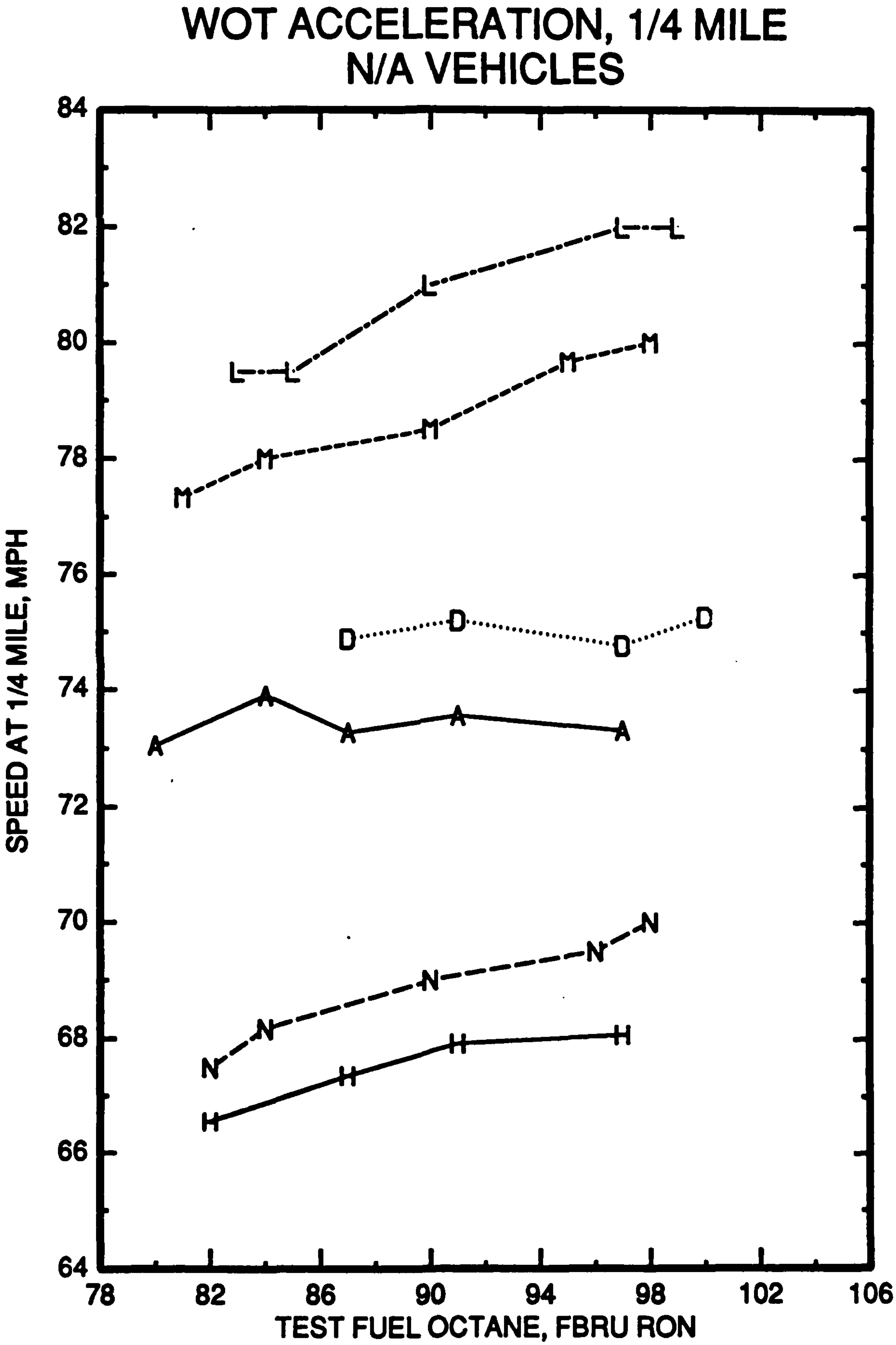

WOT ACCELERATION, 1/4 MILE
N/A VEHICLES
SPEED AT 1/4 MILE, MPH
84
82
80
78
76
74
72
70
68
66
64
78
82
86
90
94
98
102
106
TEST FUEL OCTANE, FBRU RON
L
M
D
A
N
H

FIGURE 9

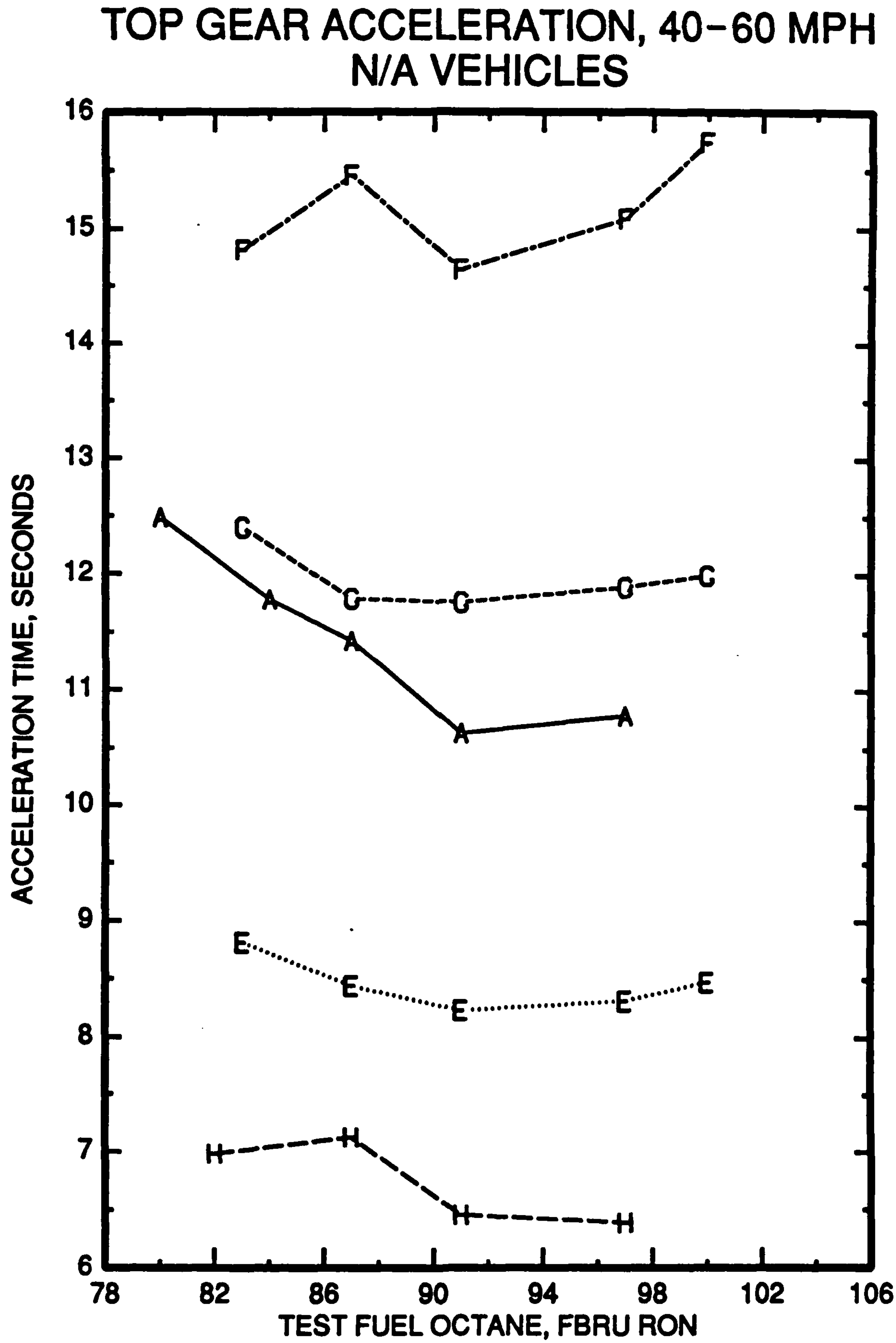

TOP GEAR ACCELERATION, 40-60 MPH
N/A VEHICLES
ACCELERATION TIME, SECONDS
16
15
14
13
12
11
10
9
8
7
6
78
82
86
90
94
98
102
106
TEST FUEL OCTANE, FBRU RON
F
C
A
E
H

FIGURE 10

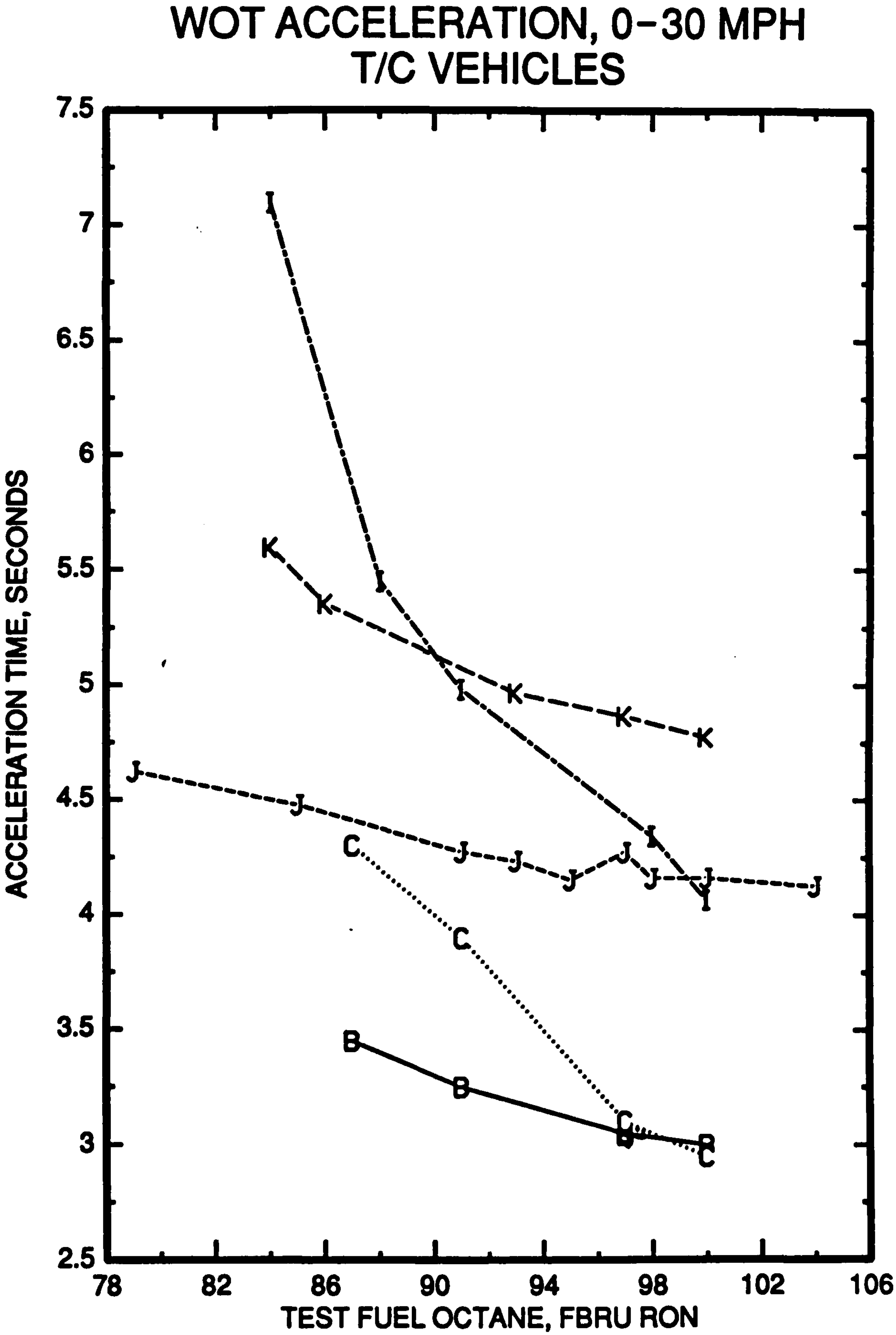
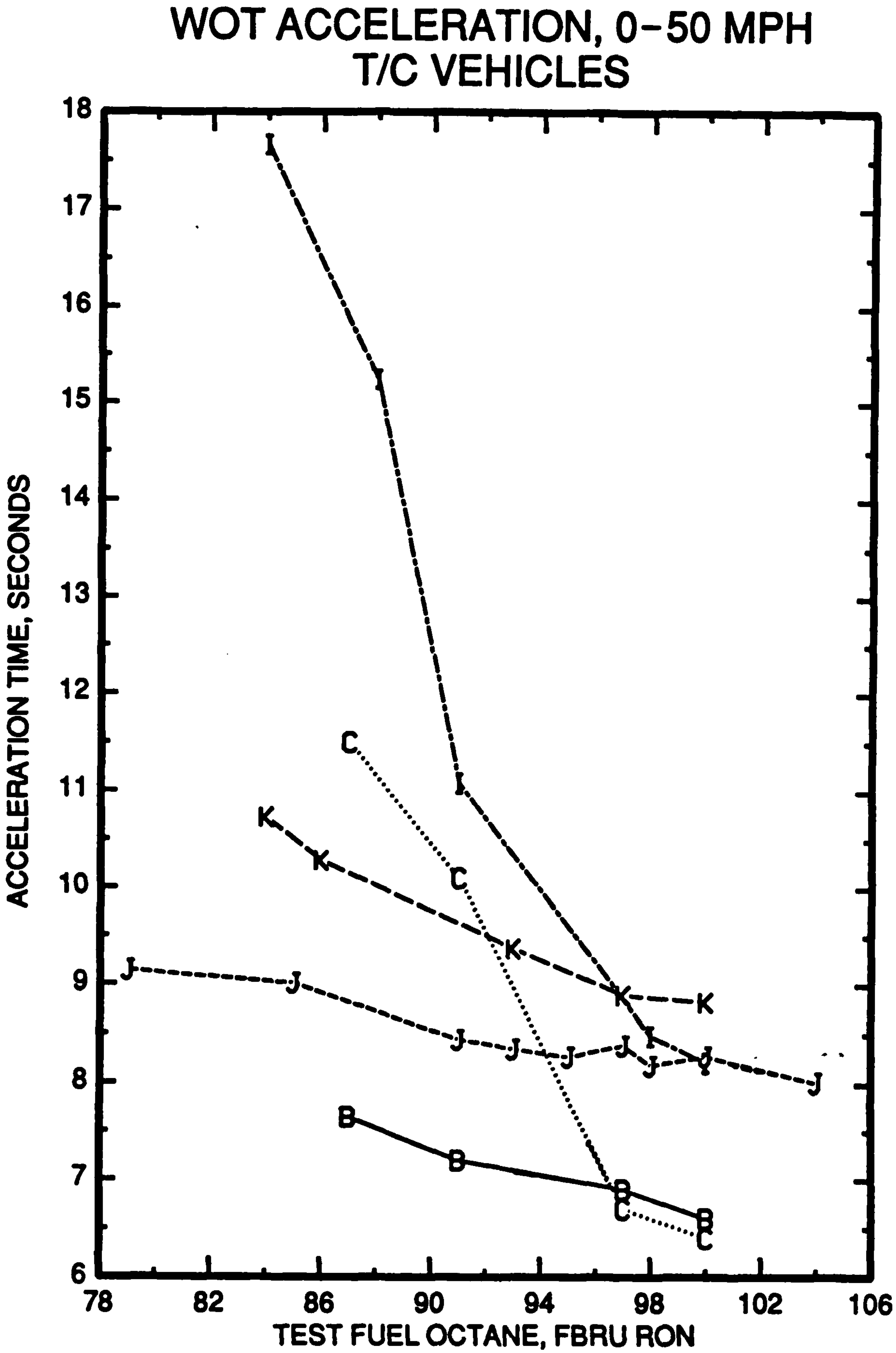

WOT ACCELERATION, 0-30 MPH
T/C VEHICLES
ACCELERATION TIME, SECONDS
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
78
82
86
90
94
98
102
106
TEST FUEL OCTANE, FBRU RON
I
K
J
C
B

FIGURE 11



WOT ACCELERATION, 0-50 MPH
T/C VEHICLES
ACCELERATION TIME, SECONDS
TEST FUEL OCTANE, FBRU RON
18
17
16
15
14
13
12
11
10
9
8
7
6
78
82
86
90
94
98
102
106
I
C
K
J
B

FIGURE 12

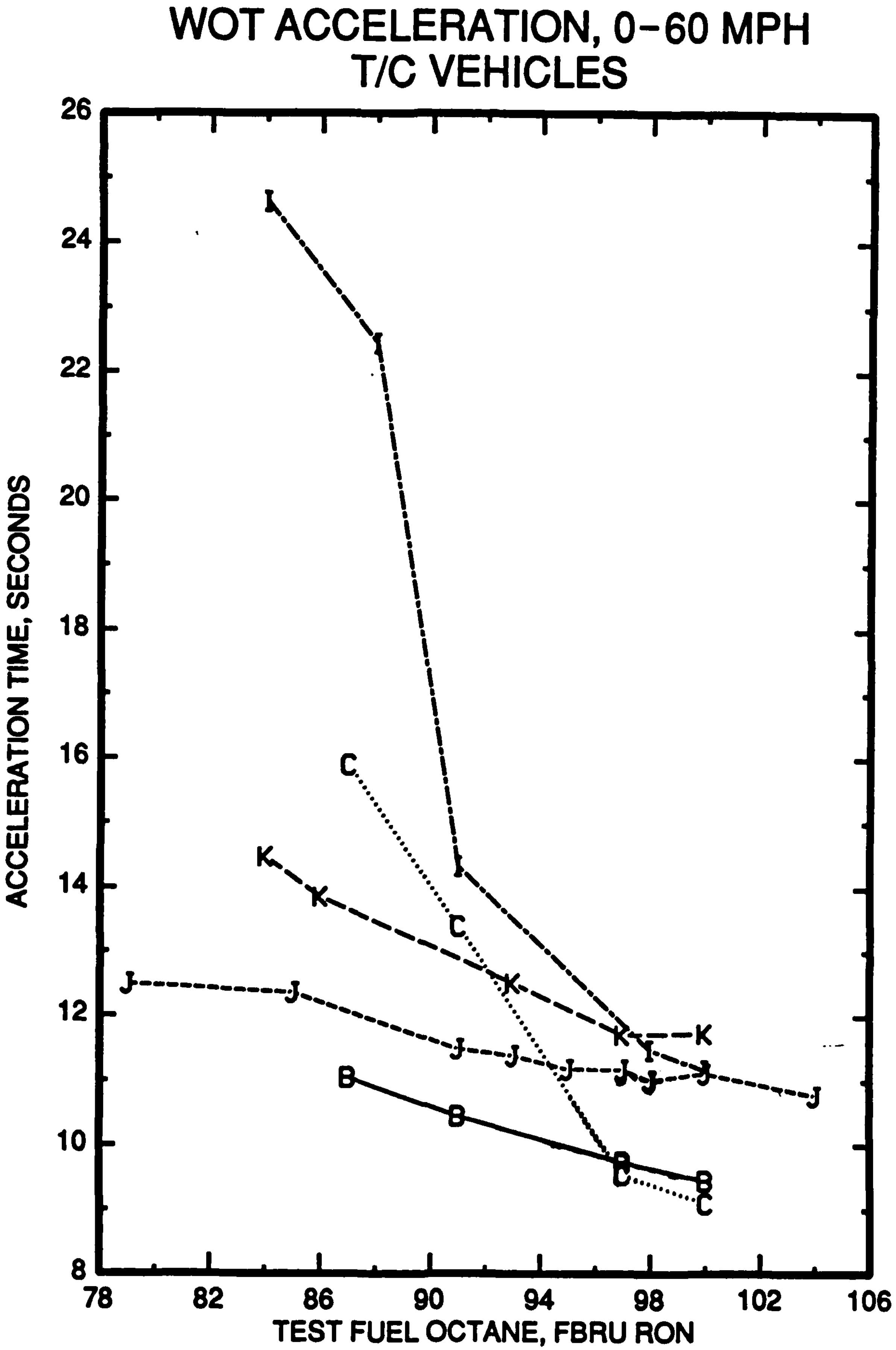

WOT ACCELERATION, 0-60 MPH
T/C VEHICLES
ACCELERATION TIME, SECONDS
TEST FUEL OCTANE, FBRU RON
26
24
22
20
18
16
14
12
10
8
78
82
86
90
94
98
102
106
I
C
K
J
B

FIGURE 13

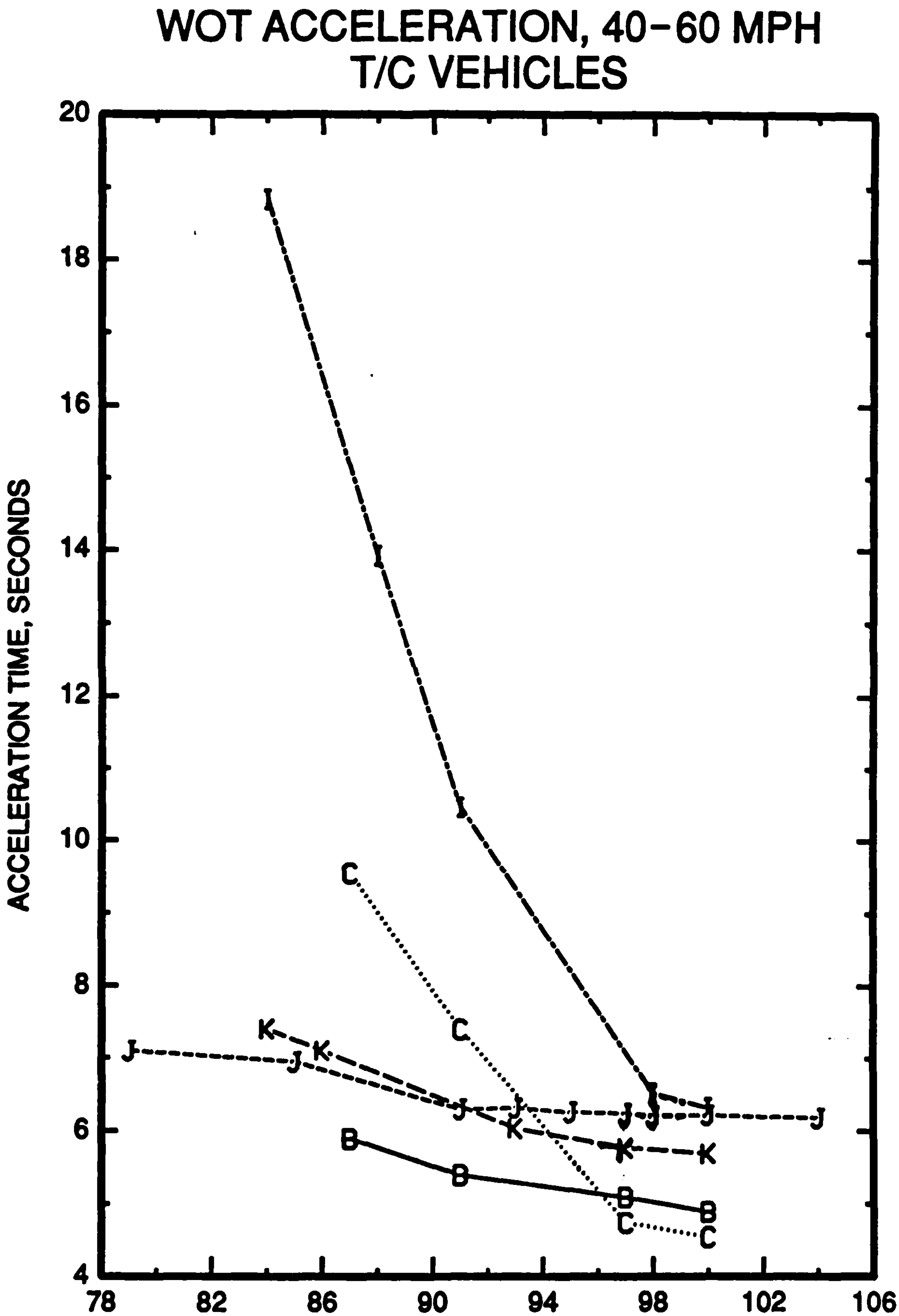

WOT ACCELERATION, 40-60 MPH
T/C VEHICLES
ACCELERATION TIME, SECONDS
TEST FUEL OCTANE, FBRU RON
20
18
16
14
12
10
8
6
4
78
82
86
90
94
98
102
106
J
K
C
B

FIGURE 14

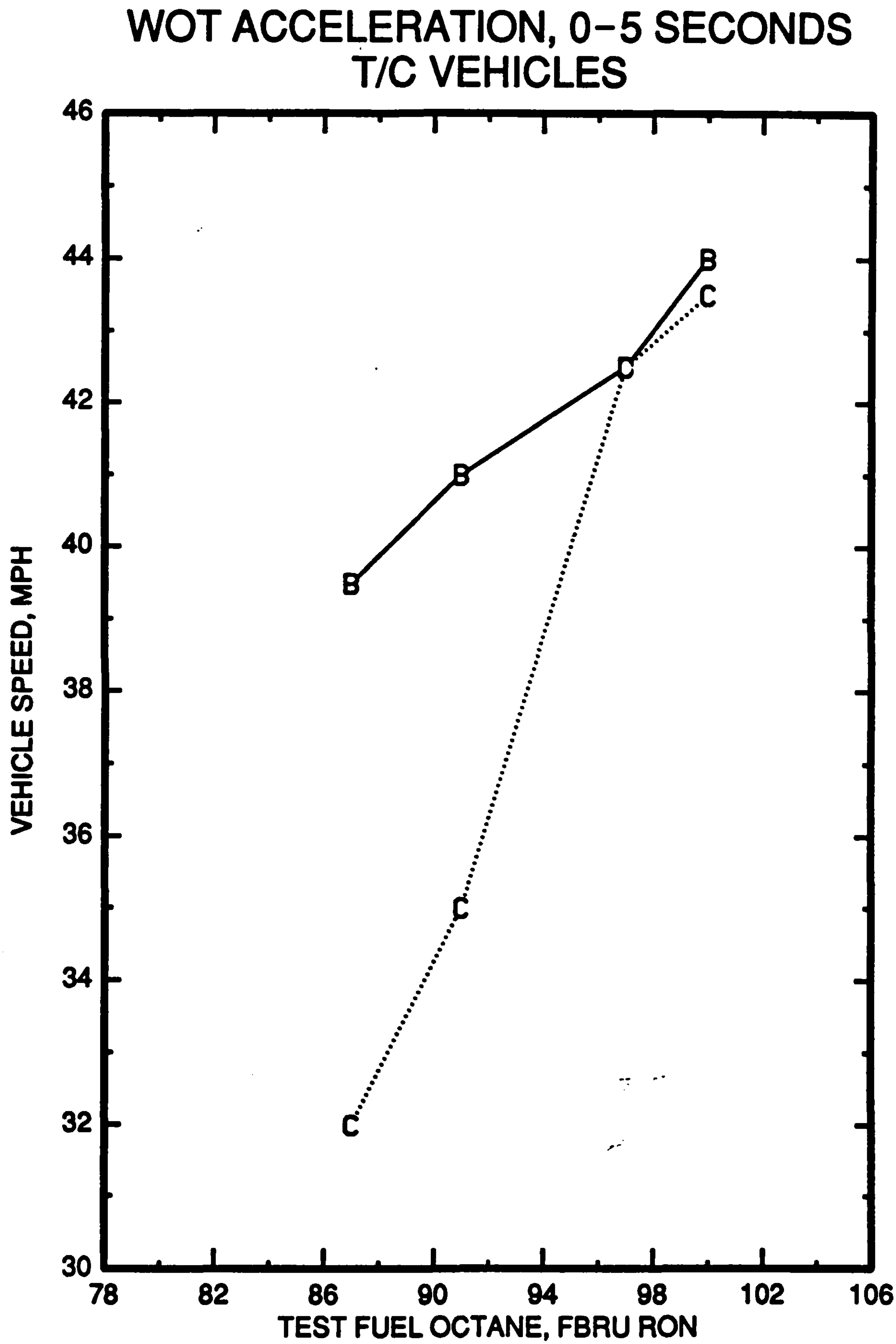

WOT ACCELERATION, 0-5 SECONDS
T/C VEHICLES
VEHICLE SPEED, MPH
TEST FUEL OCTANE, FBRU RON
46
44
42
40
38
36
34
32
30
78
82
86
90
94
98
102
106
B
C

FIGURE 15

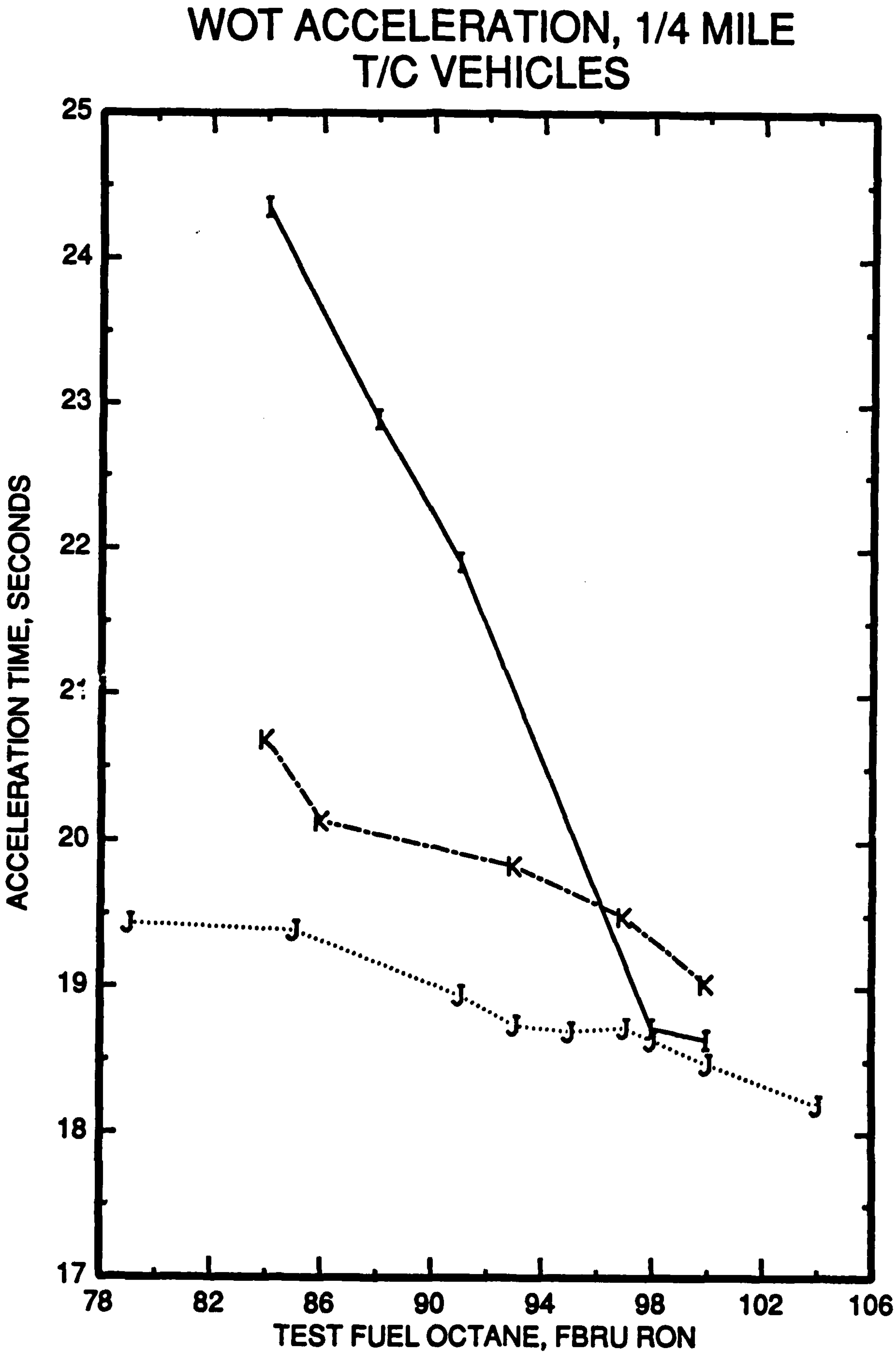
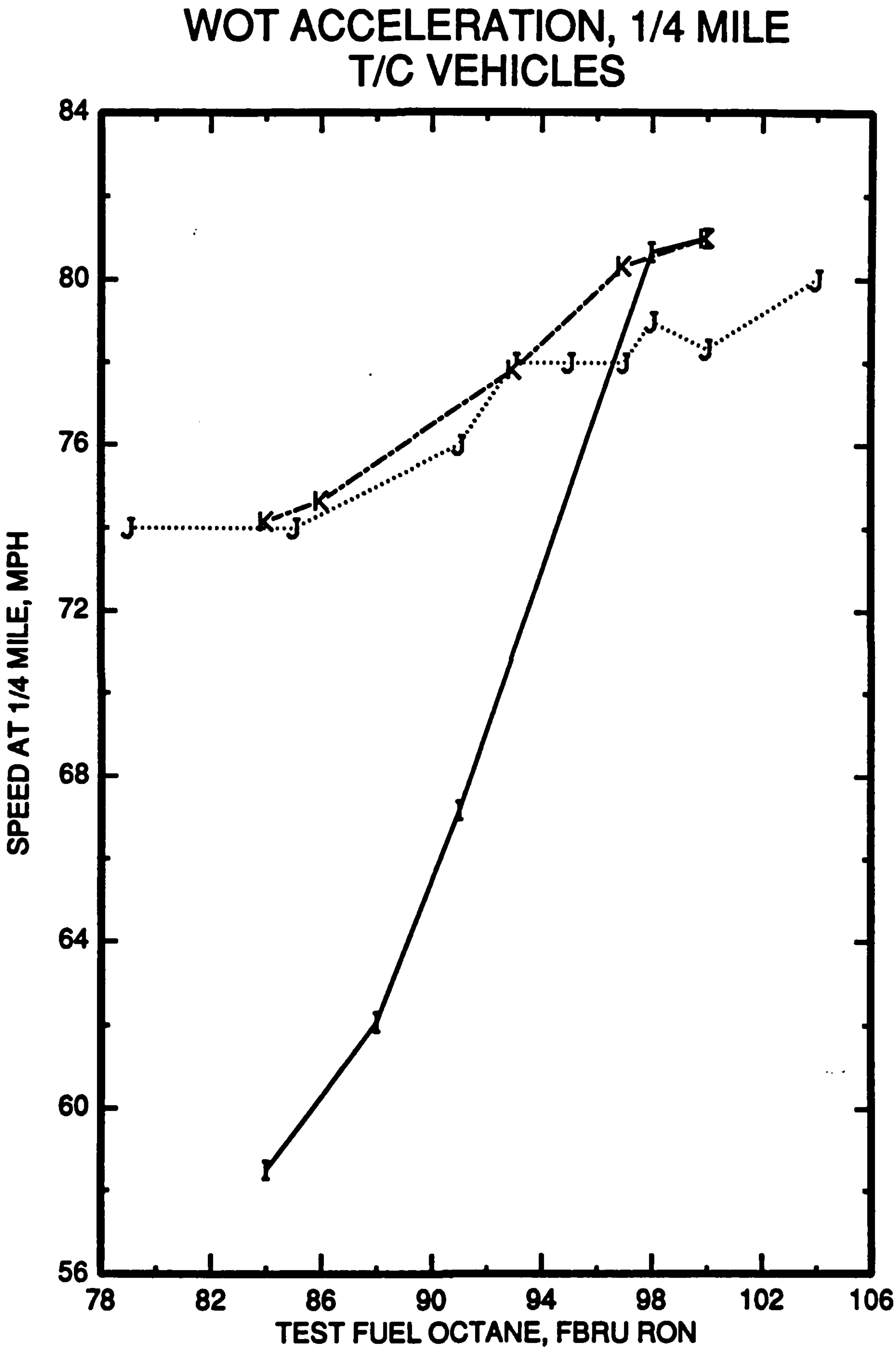

WOT ACCELERATION, 1/4 MILE
T/C VEHICLES
ACCELERATION TIME, SECONDS
25
24
23
22
21
20
19
18
17
78
82
86
90
94
98
102
106
TEST FUEL OCTANE, FBRU RON
I
J
K

FIGURE 16



WOT ACCELERATION, 1/4 MILE
T/C VEHICLES
SPEED AT 1/4 MILE, MPH
TEST FUEL OCTANE, FBRU RON
84
80
76
72
68
64
60
56
78
82
86
90
94
98
102
106

FIGURE 17

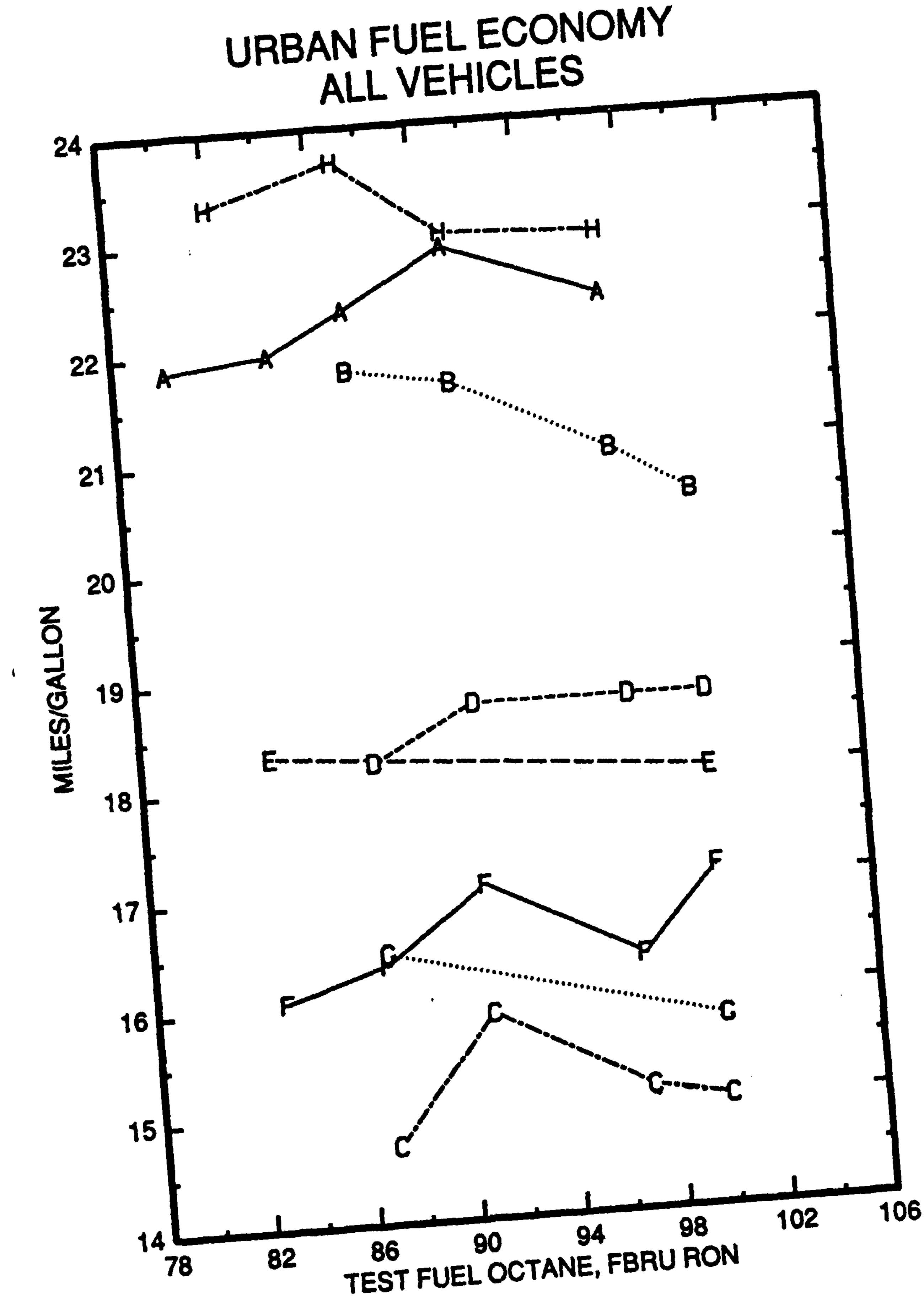

URBAN FUEL ECONOMY
ALL VEHICLES
MILES/GALLON
TEST FUEL OCTANE, FBRU RON
24
23
22
21
20
19
18
17
16
15
14
78
82
86
90
94
98
102
106
H
A
B
D
E
F
C

FIGURE 18

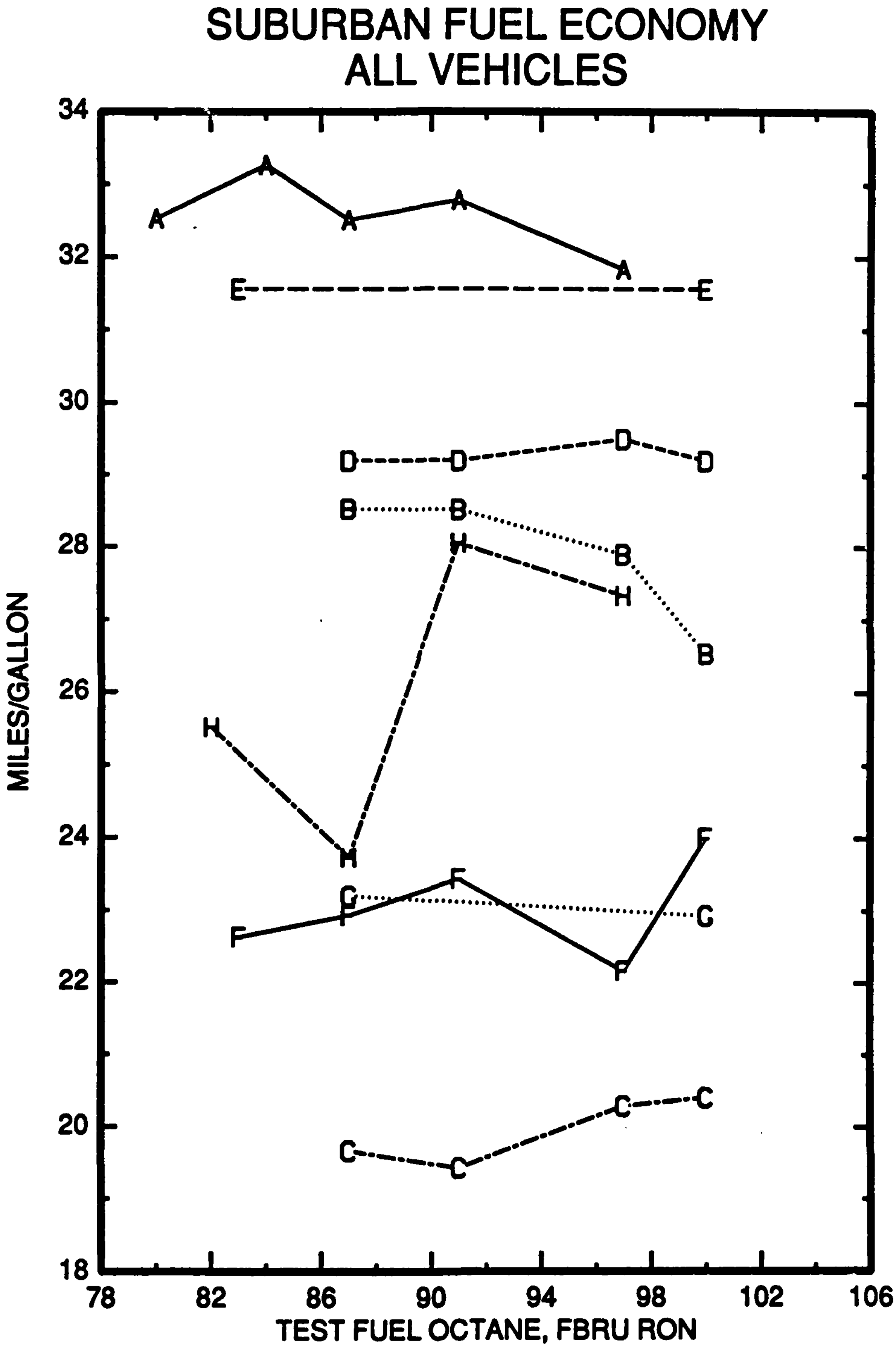

SUBURBAN FUEL ECONOMY
ALL VEHICLES
MILES/GALLON
TEST FUEL OCTANE, FBRU RON
18
20
22
24
26
28
30
32
34
78
82
86
90
94
98
102
106
A
B
C
D
E
F
H

FIGURE 19

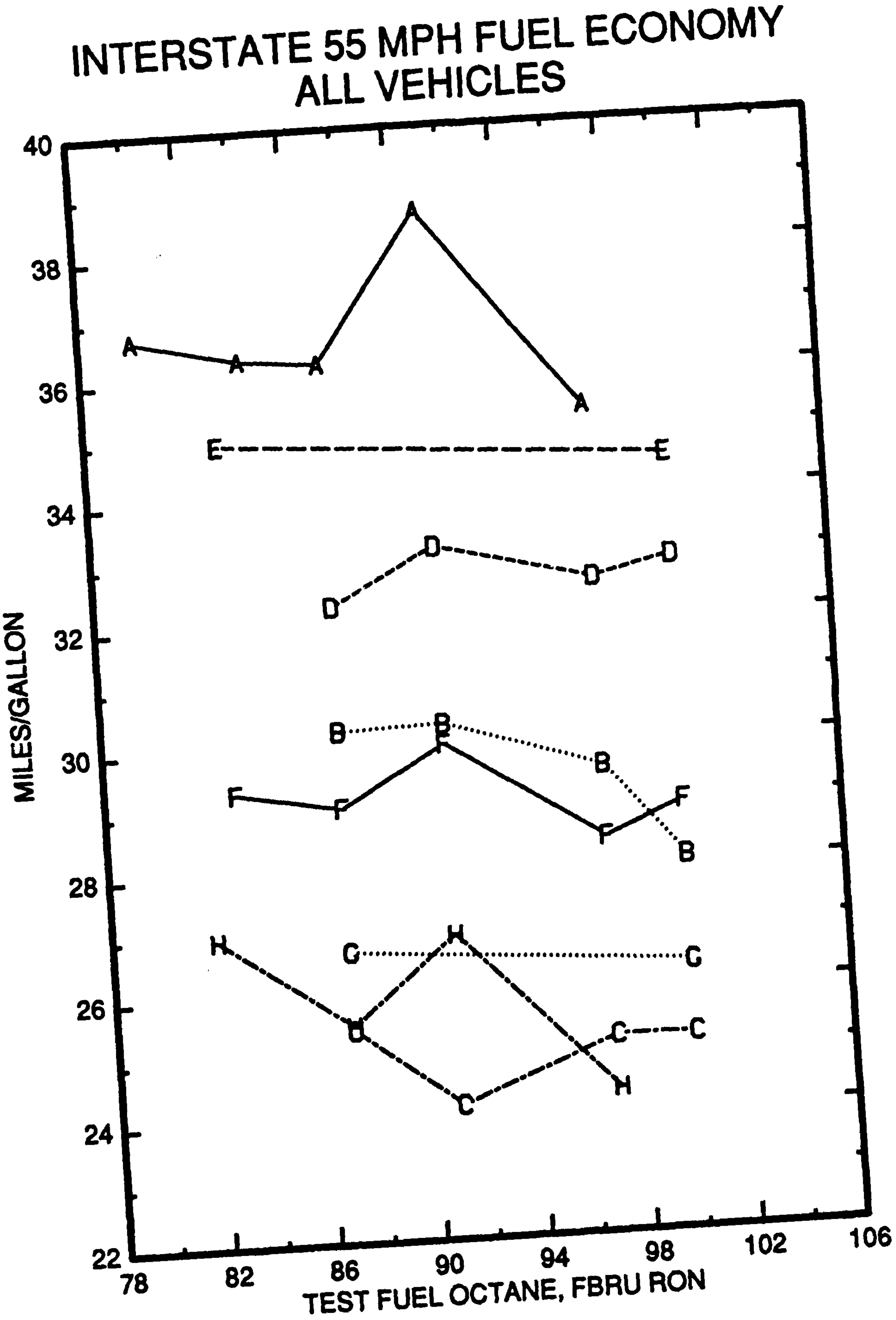

INTERSTATE 55 MPH FUEL ECONOMY
ALL VEHICLES
MILES/GALLON
40
38
36
34
32
30
28
26
24
22
78
82
86
90
94
98
102
106
TEST FUEL OCTANE, FBRU RON
A
B
C
D
E
F
G
H

FIGURE 20

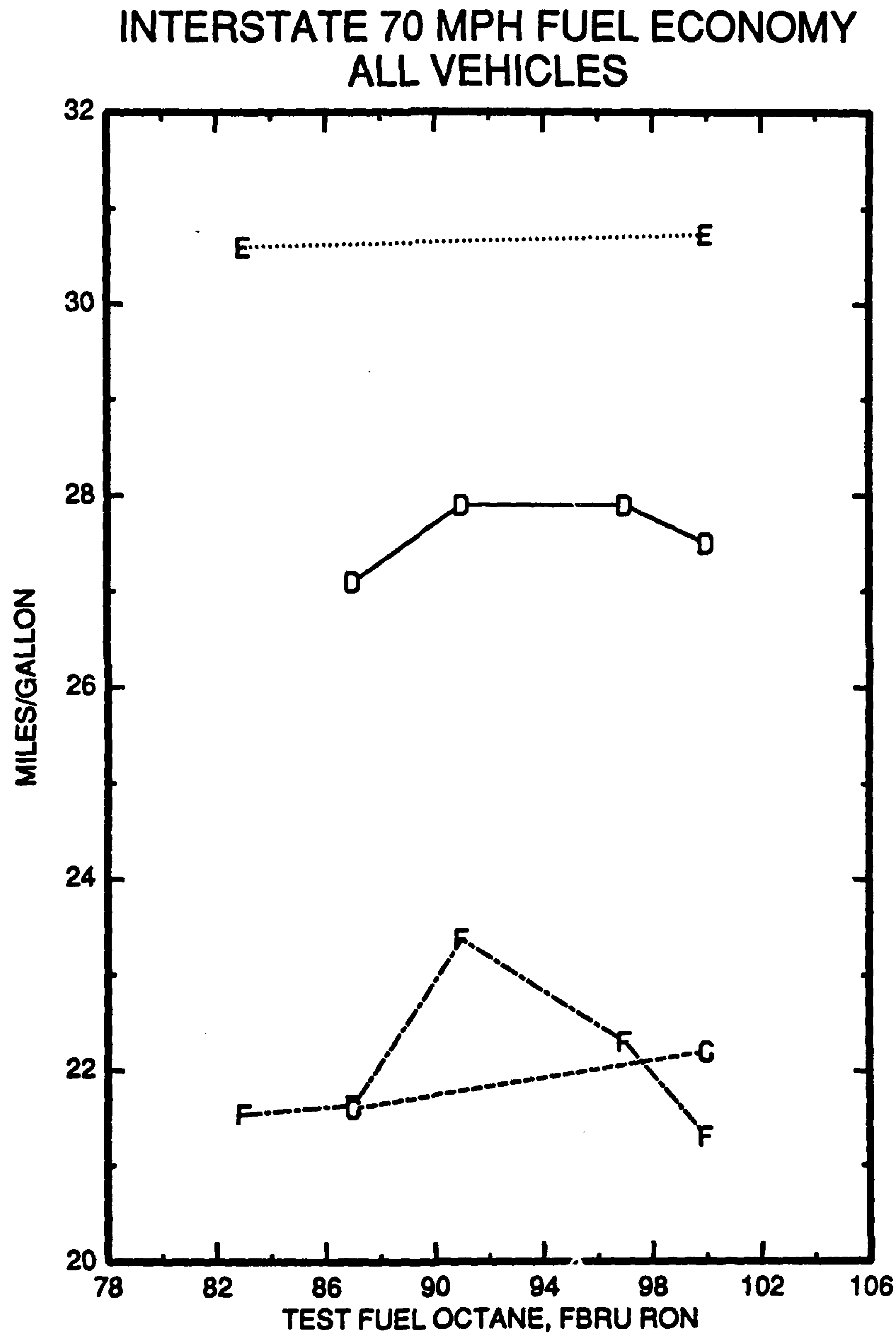

INTERSTATE 70 MPH FUEL ECONOMY
ALL VEHICLES
MILES/GALLON
TEST FUEL OCTANE, FBRU RON
32
30
28
26
24
22
20
78
82
86
90
94
98
102
106
E
E
D
D
D
D
F
F
F
F
C
C

FIGURE 21

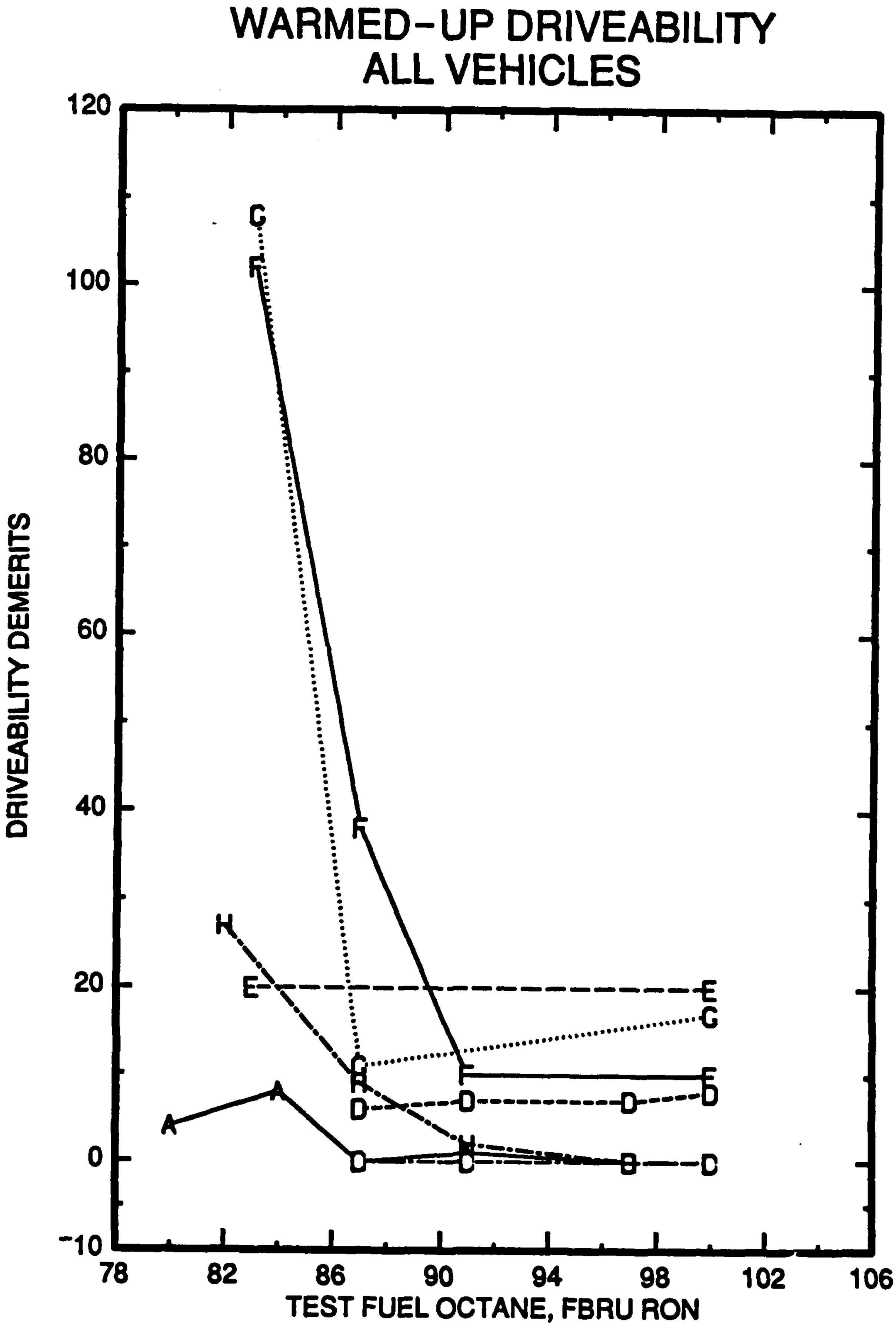

WARMED-UP DRIVEABILITY
ALL VEHICLES
DRIVEABILITY DEMERITS
TEST FUEL OCTANE, FBRU RON
120
100
80
60
40
20
0
-10
78
82
86
90
94
98
102
106
A
B
C
D
E
F
H

FIGURE 22

Effect of Premium Fuel Relative to Regular Fuel

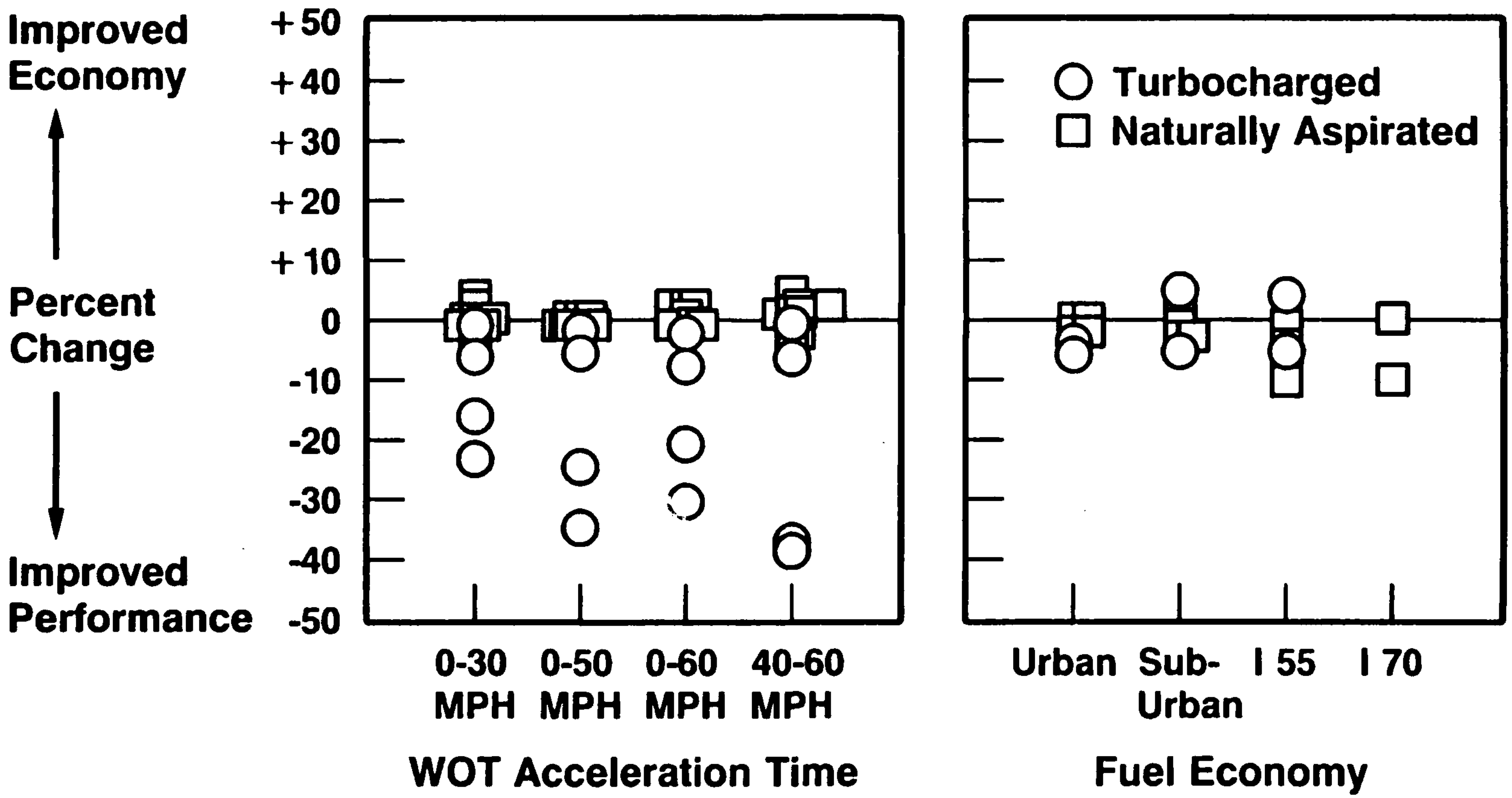


FIGURE 23

WOT ACCELERATION, 0-30 MPH
NORMALIZED RESULTS

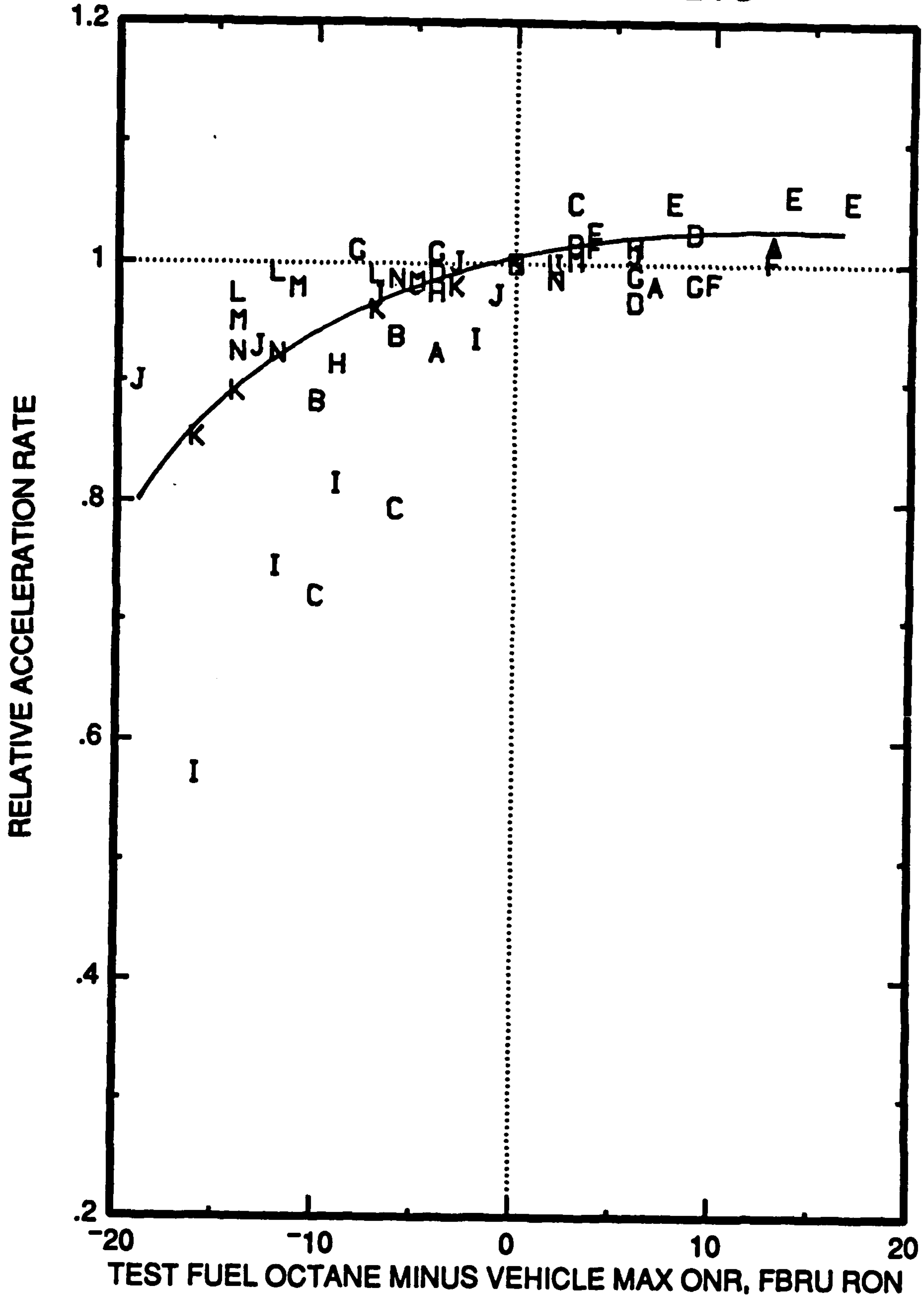


FIGURE 24

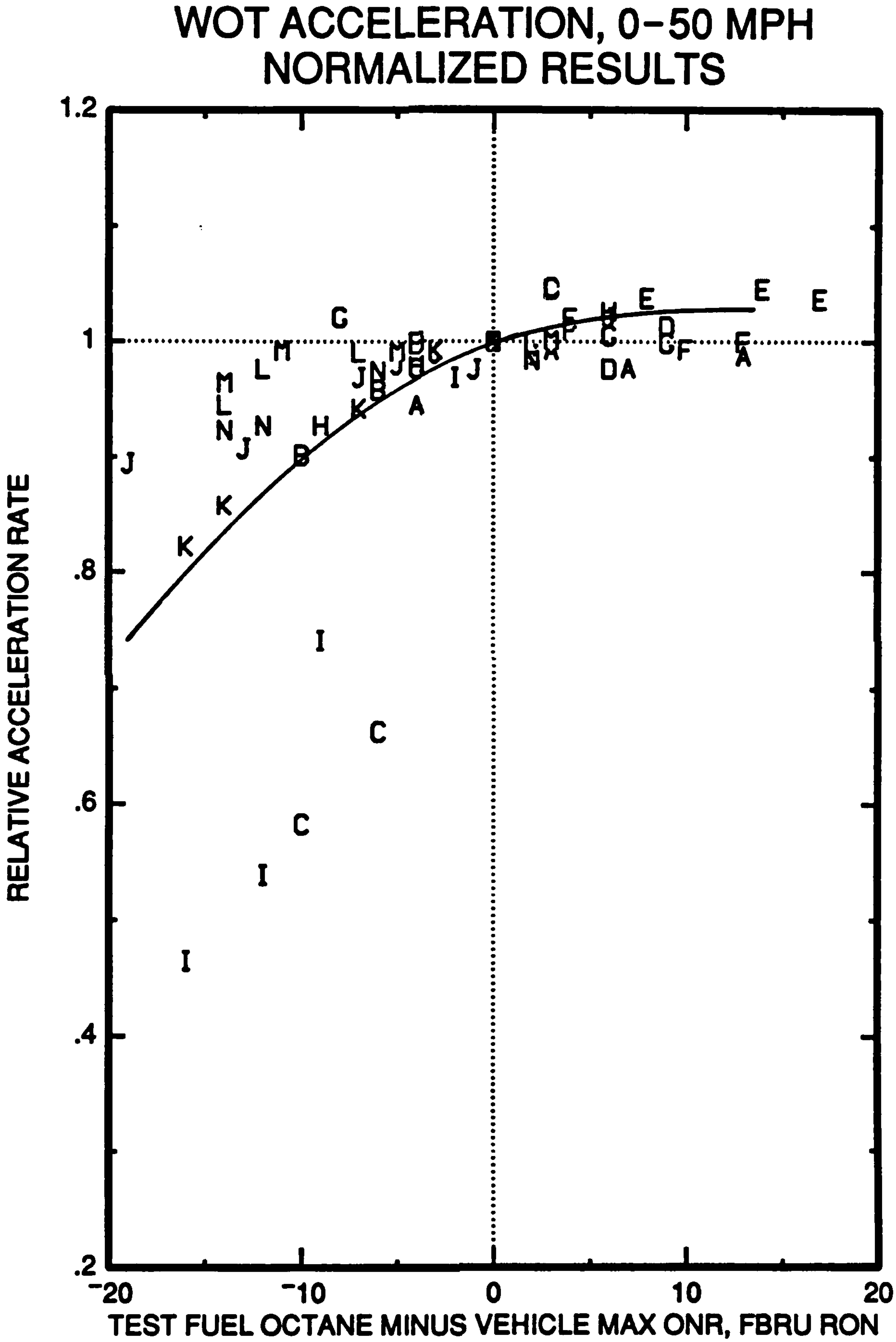

WOT ACCELERATION, 0-50 MPH
NORMALIZED RESULTS
RELATIVE ACCELERATION RATE
1.2
1
.8
.6
.4
.2
-20
-10
0
10
20
TEST FUEL OCTANE MINUS VEHICLE MAX ONR, FBRU RON

FIGURE 25

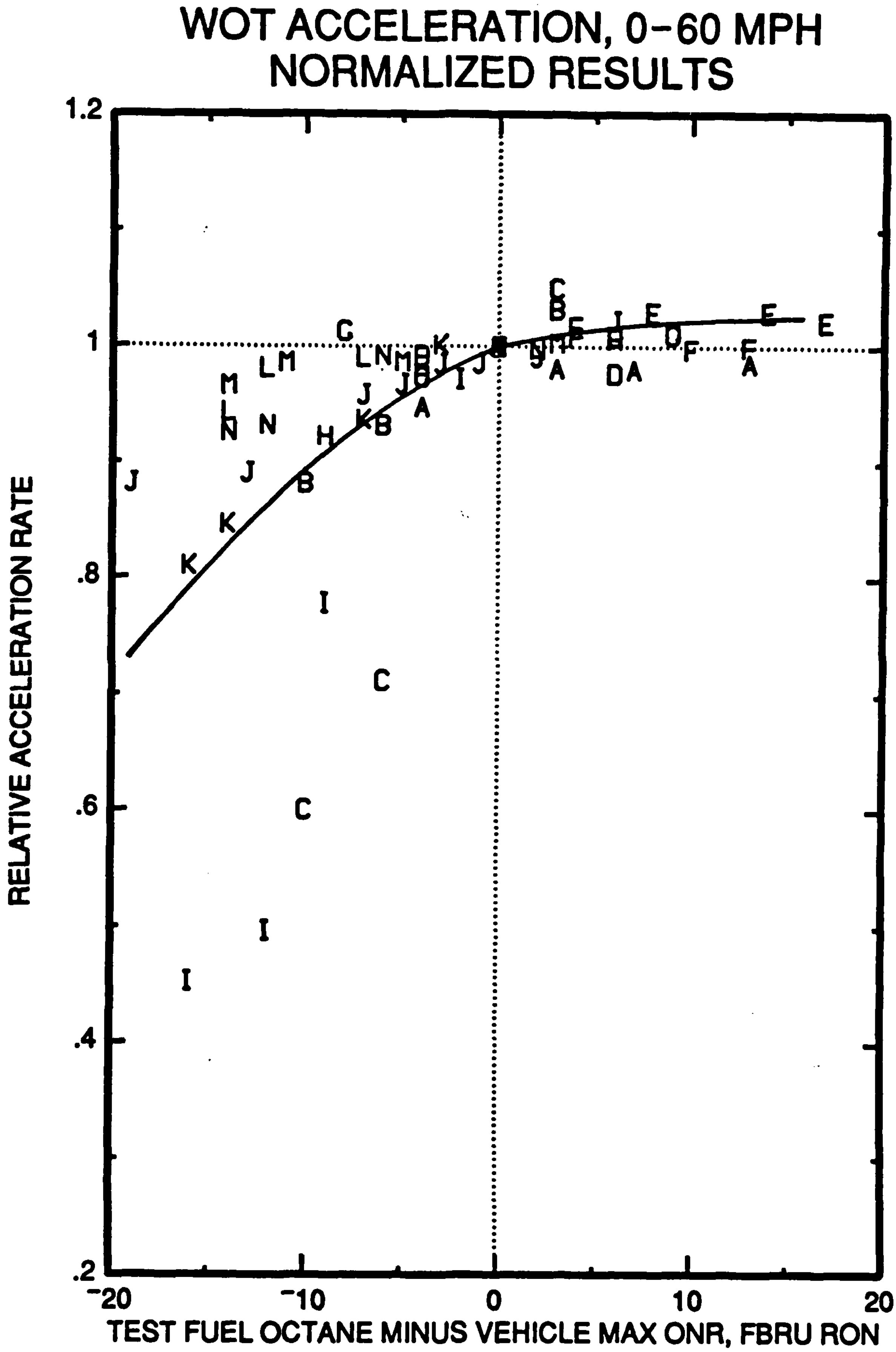

WOT ACCELERATION, 0-60 MPH
NORMALIZED RESULTS
RELATIVE ACCELERATION RATE
1.2
1
.8
.6
.4
.2
-20
-10
0
10
20
TEST FUEL OCTANE MINUS VEHICLE MAX ONR, FBRU RON

FIGURE 26

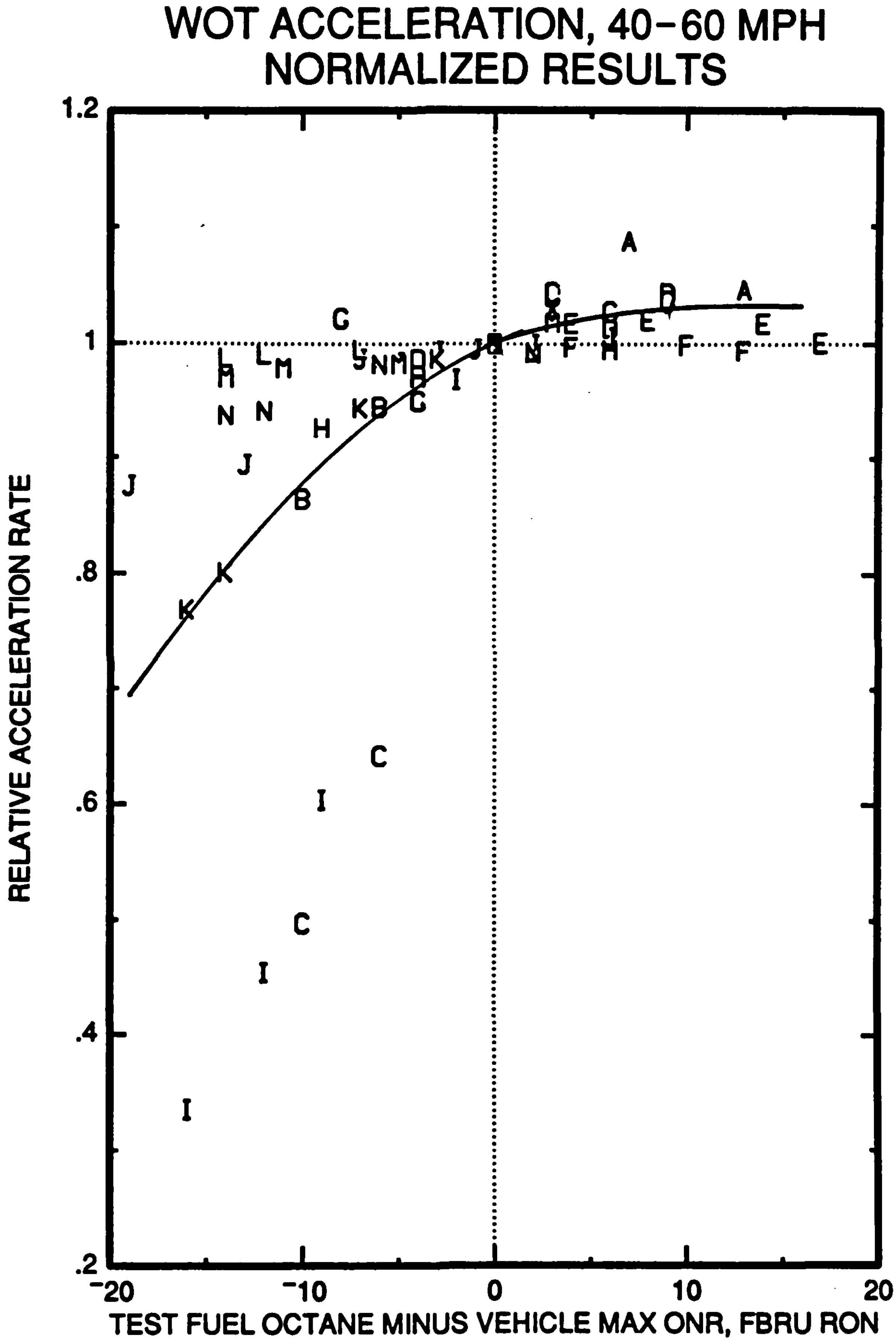
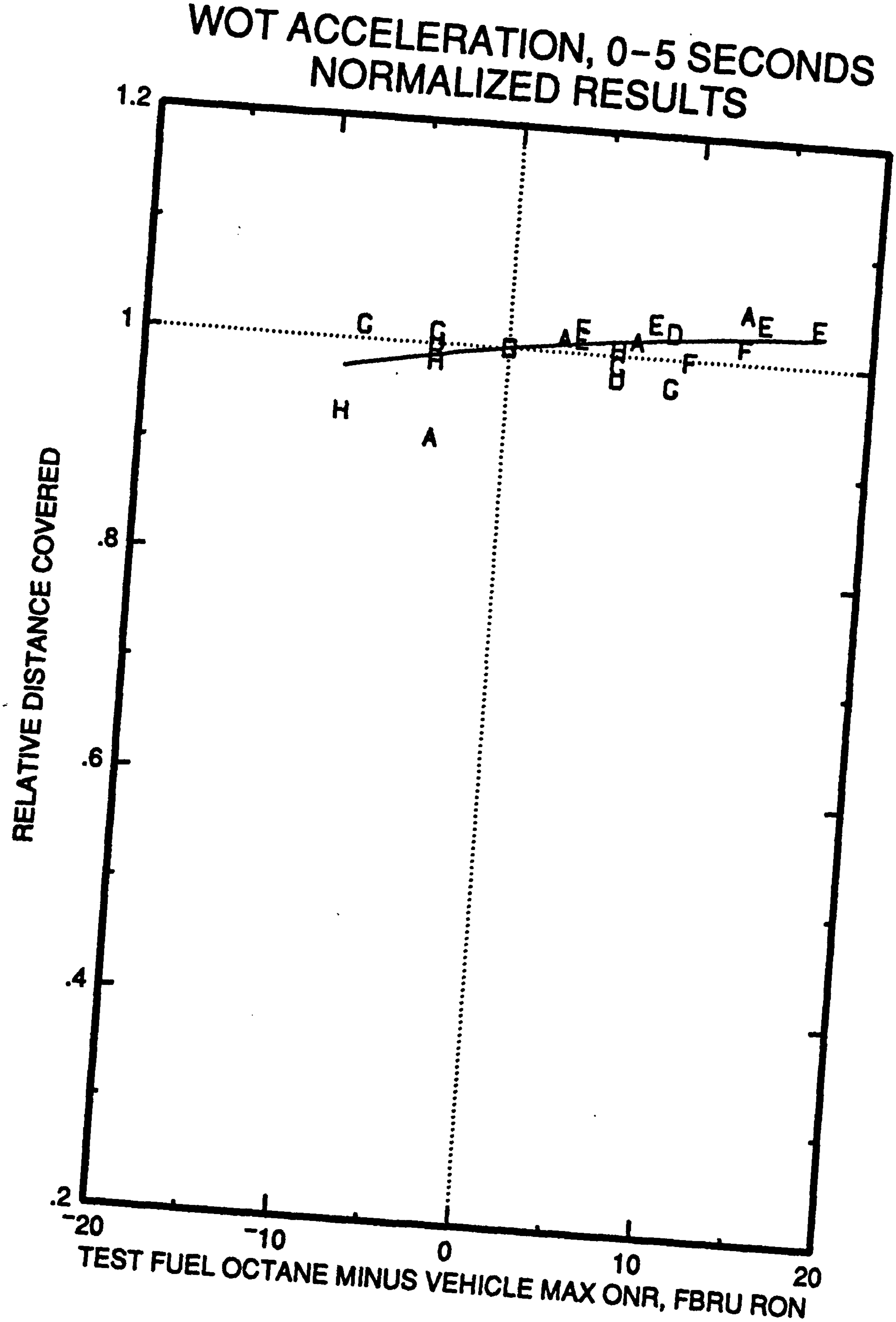

WOT ACCELERATION, 40-60 MPH
NORMALIZED RESULTS
RELATIVE ACCELERATION RATE
TEST FUEL OCTANE MINUS VEHICLE MAX ONR, FBRU RON
1.2
1
.8
.6
.4
.2
-20
-10
0
10
20

FIGURE 27



WOT ACCELERATION, 0-5 SECONDS
NORMALIZED RESULTS
RELATIVE DISTANCE COVERED
1.2
1
.8
.6
.4
.2
-20
-10
0
10
20
TEST FUEL OCTANE MINUS VEHICLE MAX ONR, FBRU RON

FIGURE 28

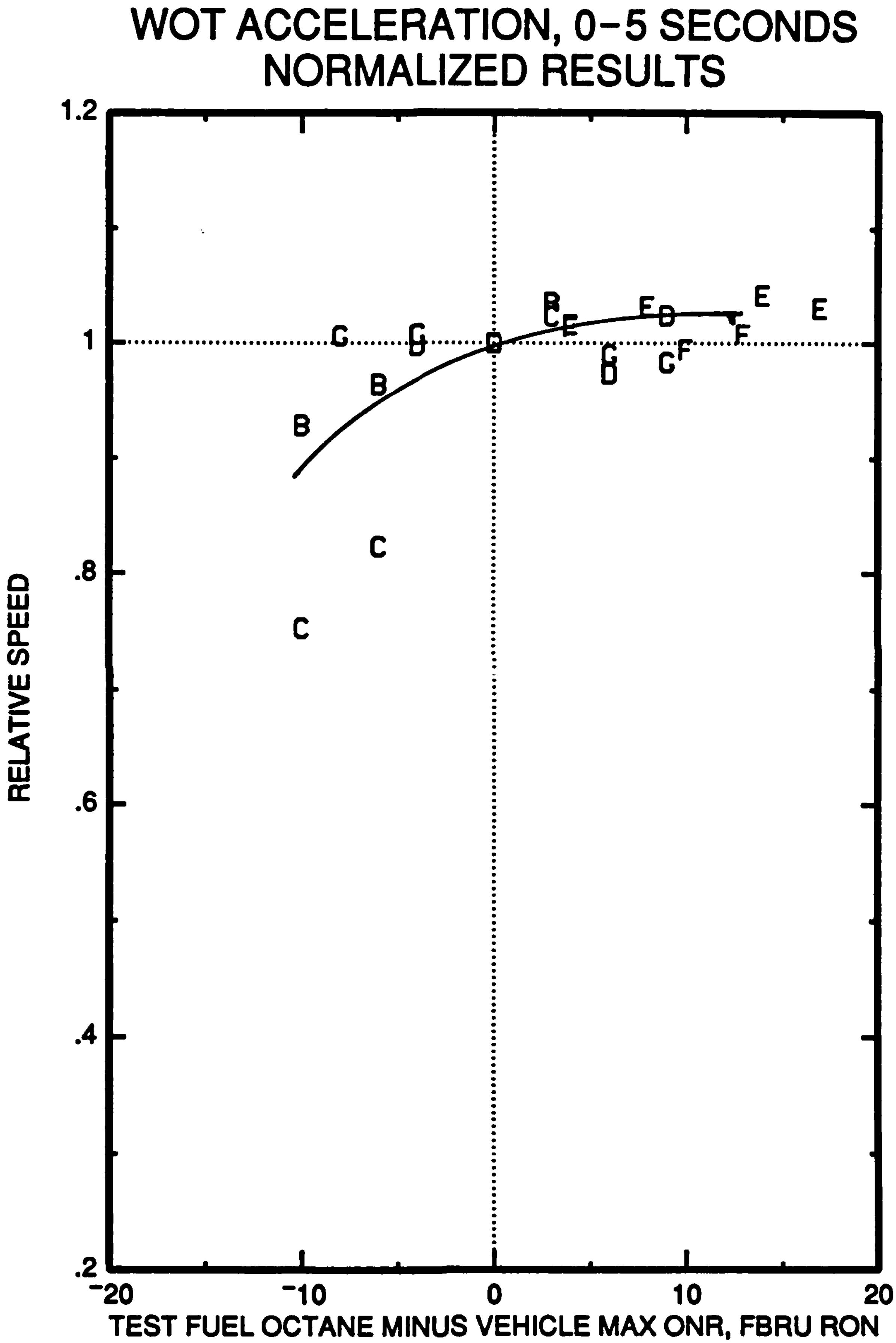

WOT ACCELERATION, 0-5 SECONDS
NORMALIZED RESULTS
RELATIVE SPEED
TEST FUEL OCTANE MINUS VEHICLE MAX ONR, FBRU RON
1.2
1
.8
.6
.4
.2
-20
-10
0
10
20

FIGURE 29

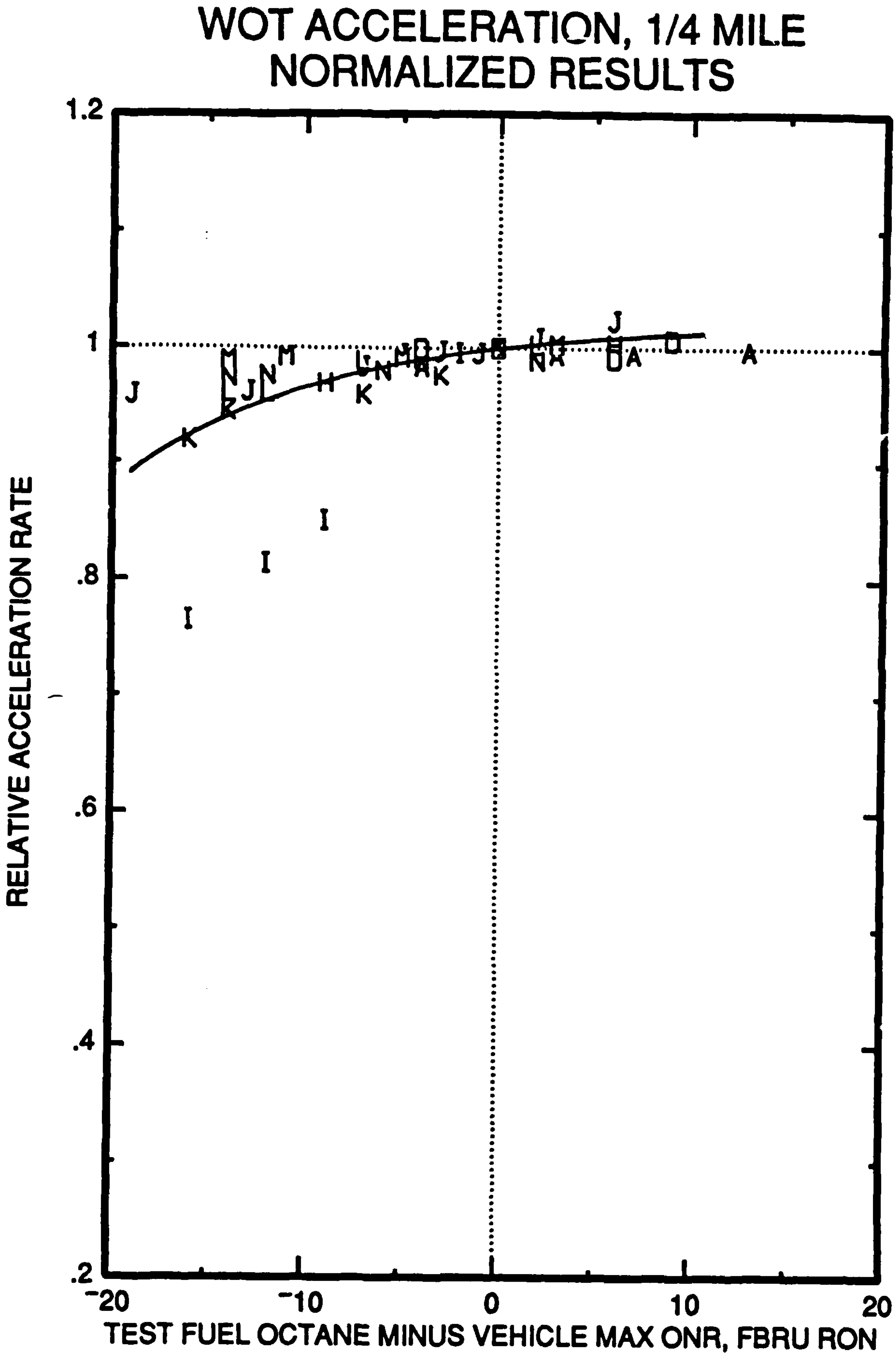

WOT ACCELERATION, 1/4 MILE
NORMALIZED RESULTS
RELATIVE ACCELERATION RATE
TEST FUEL OCTANE MINUS VEHICLE MAX ONR, FBRU RON
1.2
1
.8
.6
.4
.2
-20
-10
0
10
20

FIGURE 30

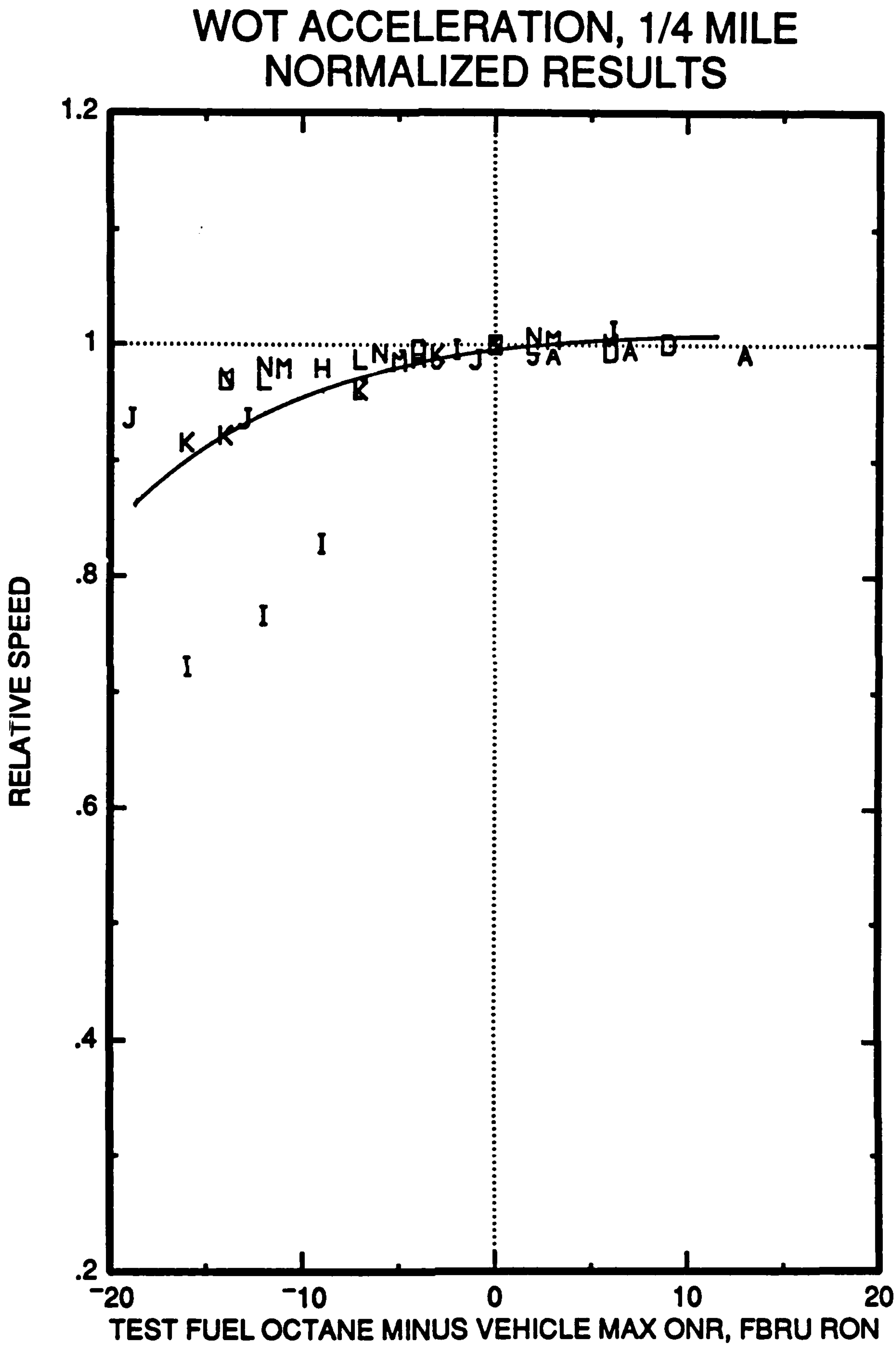

WOT ACCELERATION, 1/4 MILE
NORMALIZED RESULTS
RELATIVE SPEED
1.2
1
.8
.6
.4
.2
-20
-10
0
10
20
TEST FUEL OCTANE MINUS VEHICLE MAX ONR, FBRU RON

FIGURE 31

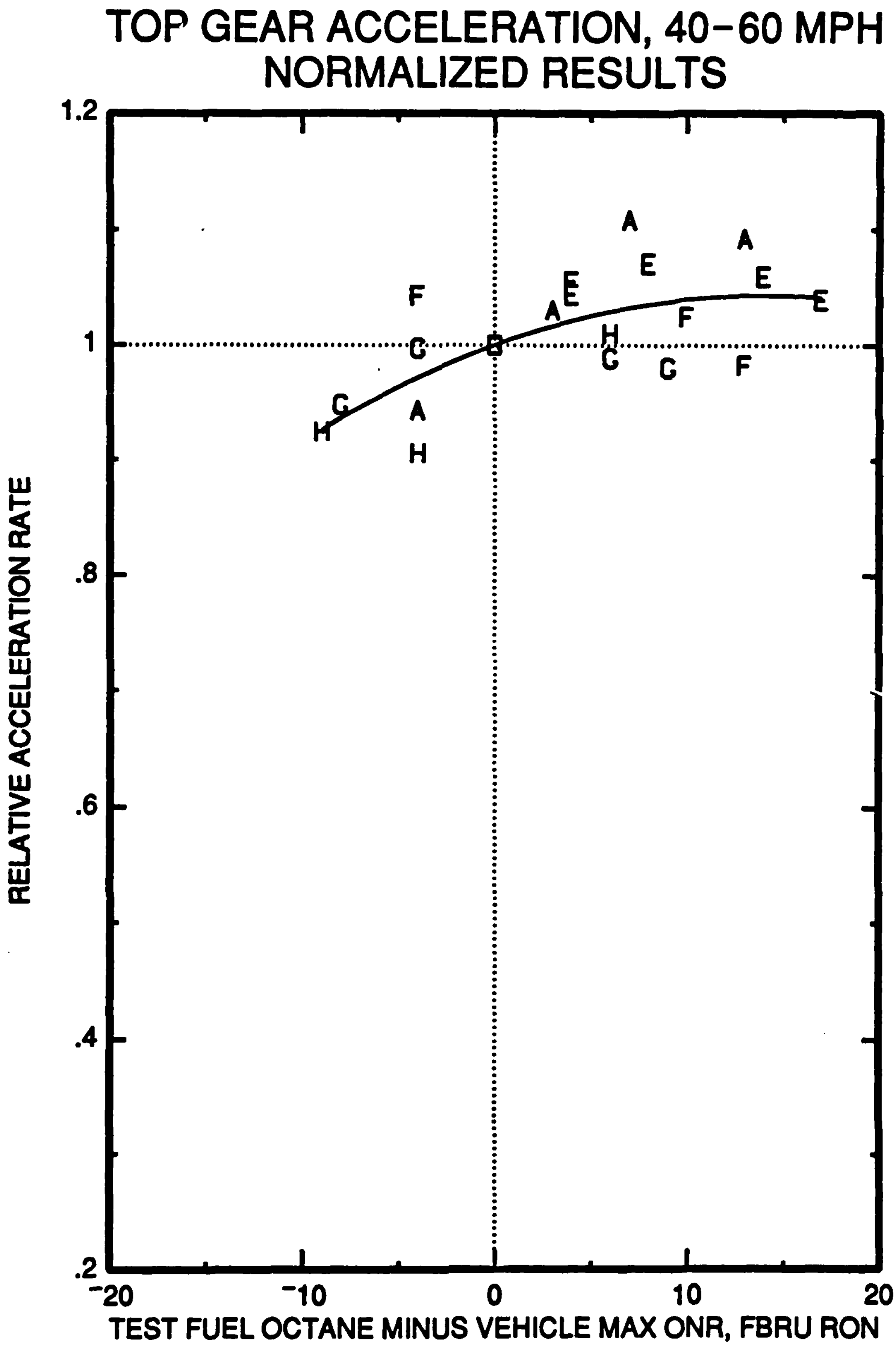

TOP GEAR ACCELERATION, 40-60 MPH
NORMALIZED RESULTS
RELATIVE ACCELERATION RATE
TEST FUEL OCTANE MINUS VEHICLE MAX ONR, FBRU RON
1.2
1
.8
.6
.4
.2
-20
-10
0
10
20

FIGURE 32

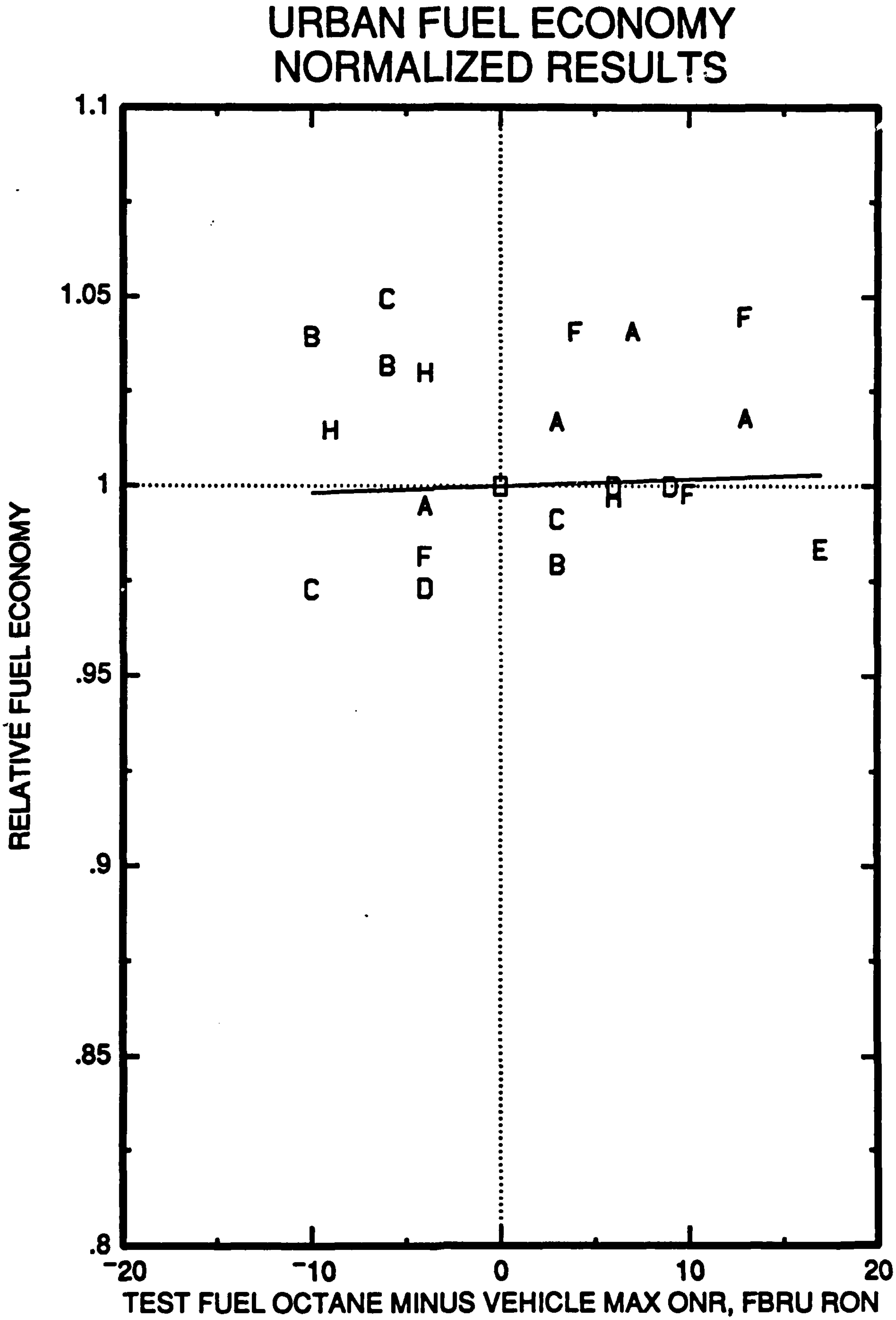

URBAN FUEL ECONOMY
NORMALIZED RESULTS
RELATIVE FUEL ECONOMY
TEST FUEL OCTANE MINUS VEHICLE MAX ONR, FBRU RON
1.1
1.05
1
.95
.9
.85
.8
-20
-10
0
10
20

FIGURE 33

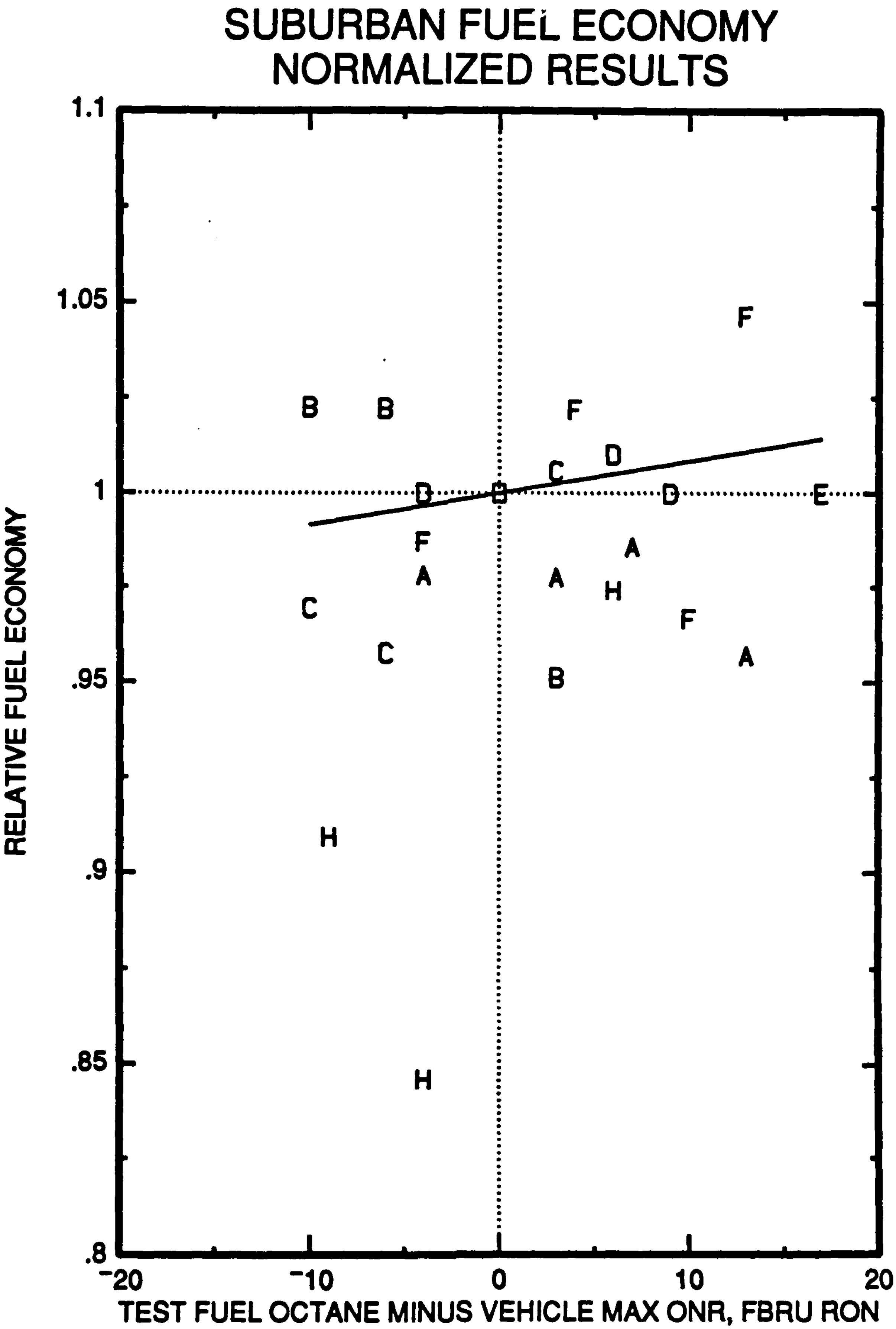

SUBURBAN FUEL ECONOMY
NORMALIZED RESULTS
RELATIVE FUEL ECONOMY
1.1
1.05
1
.95
.9
.85
.8
−20
−10
0
10
20
TEST FUEL OCTANE MINUS VEHICLE MAX ONR, FBRU RON

FIGURE 34

INTERSTATE 55 MPH FUEL ECONOMY NORMALIZED RESULTS

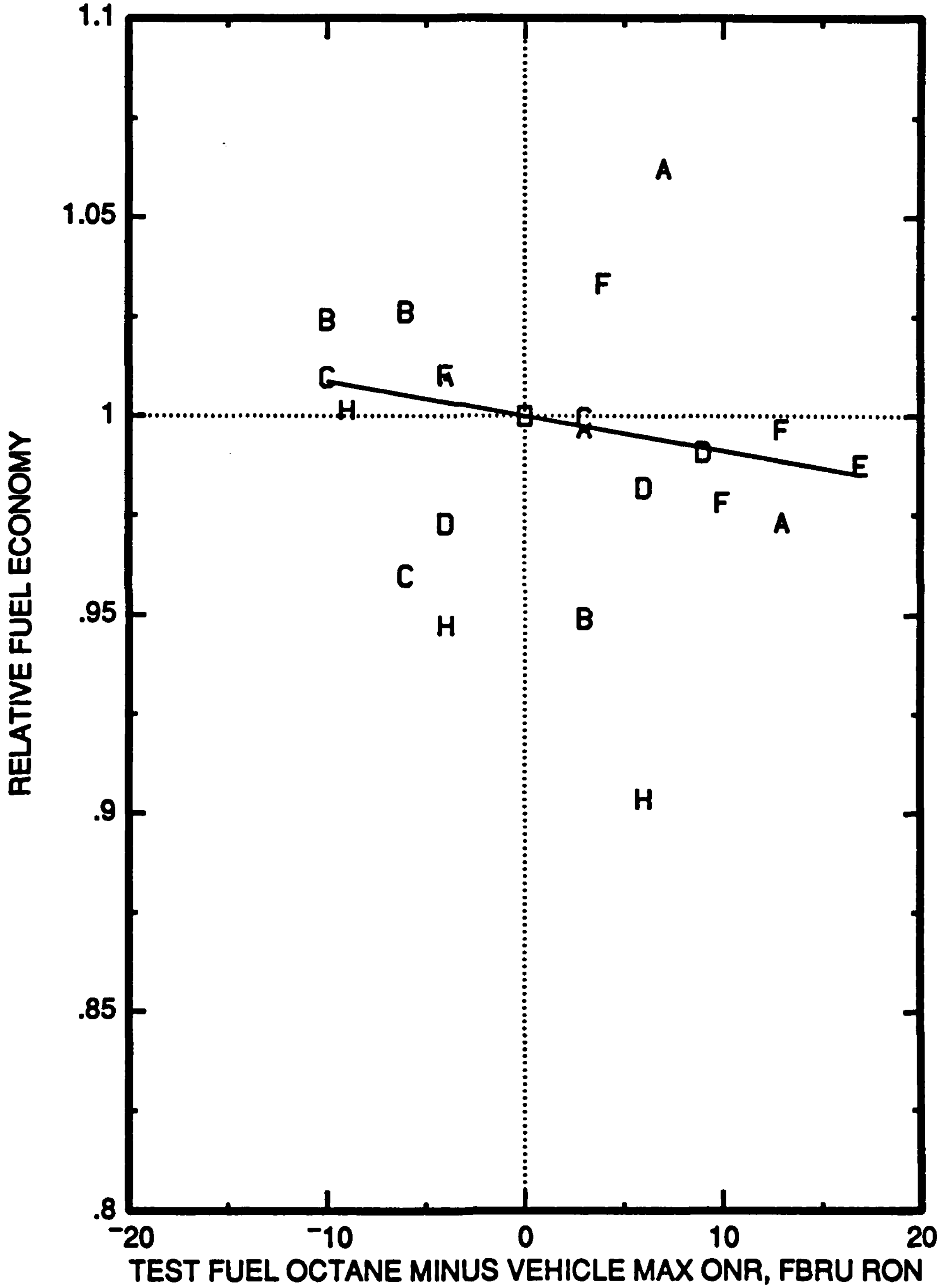


FIGURE 35

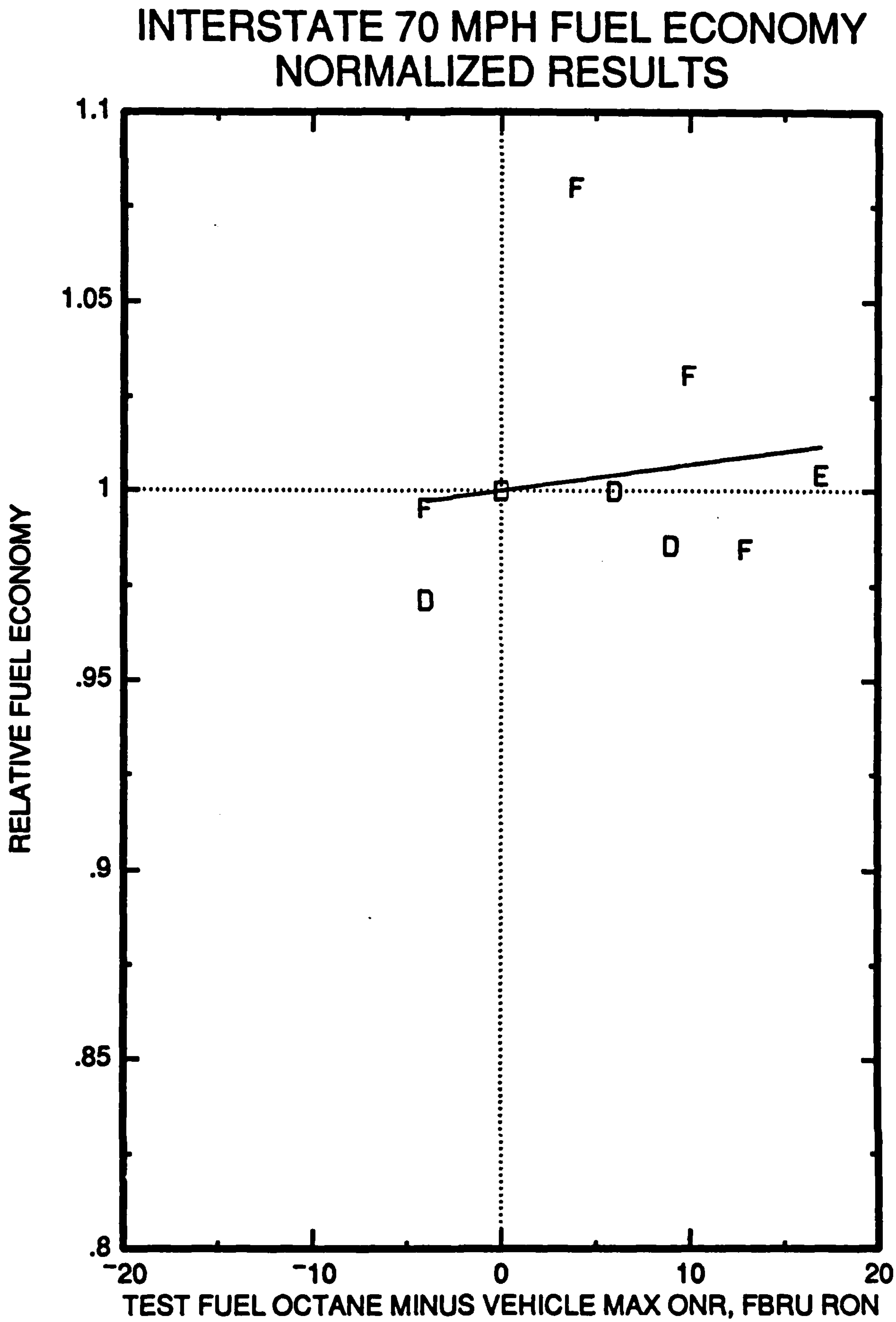
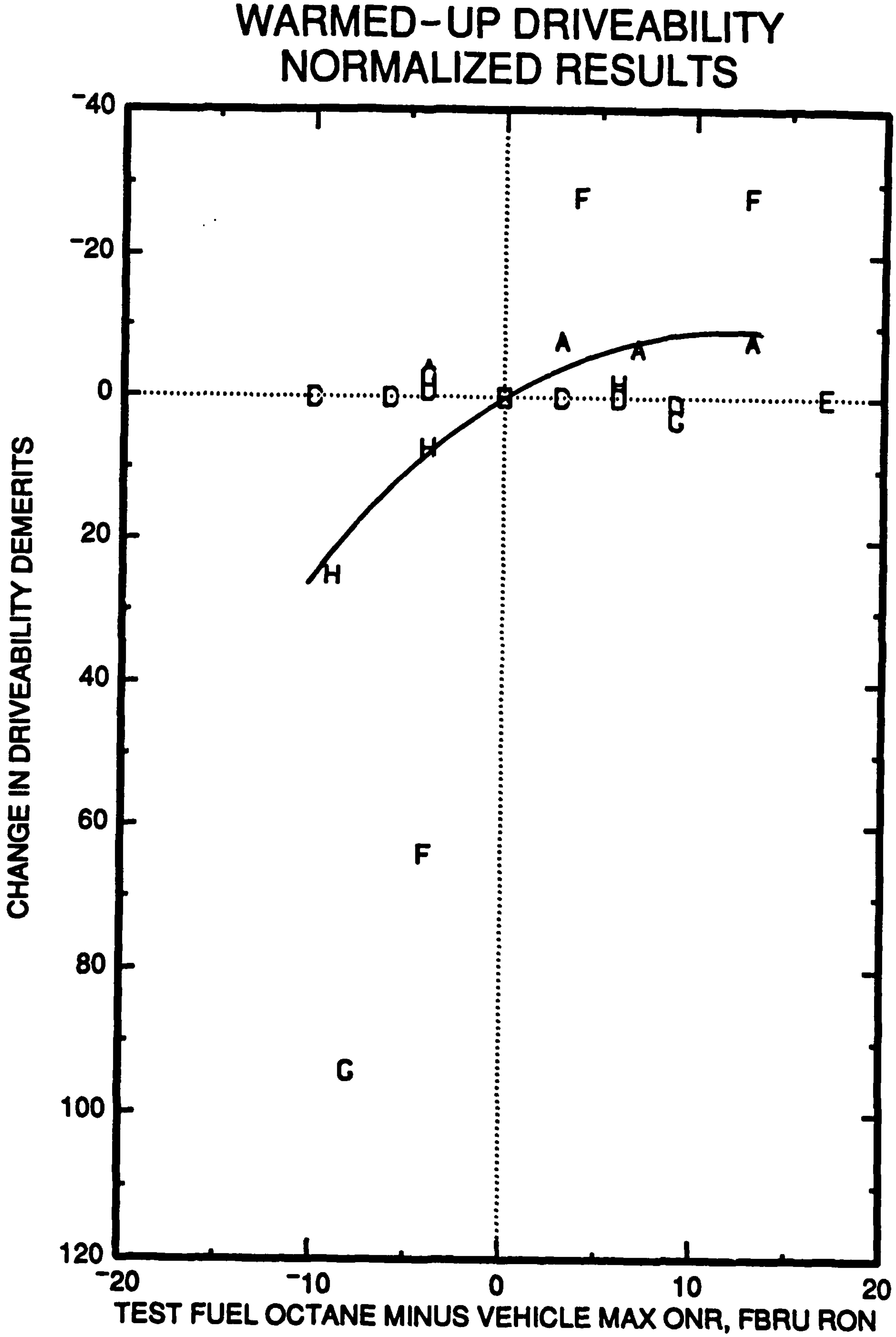

INTERSTATE 70 MPH FUEL ECONOMY
NORMALIZED RESULTS
1.1
1.05
1
.95
.9
.85
.8
RELATIVE FUEL ECONOMY
−20
−10
0
10
20
TEST FUEL OCTANE MINUS VEHICLE MAX ONR, FBRU RON
F
F
E
D
F
D
F
D

FIGURE 36


WARMED-UP DRIVEABILITY
NORMALIZED RESULTS
CHANGE IN DRIVEABILITY DEMERITS
TEST FUEL OCTANE MINUS VEHICLE MAX ONR, FBRU RON
-40
-20
0
20
40
60
80
100
120
-20
-10
0
10
20

APPENDIX A

PARTICIPATING LABORATORIES

Participating Laboratories

Amoco Oil Company

Chevron Research and Technology Company

General Motors Research Laboratories

Mobil Research and Development Corporation

Unocal

APPENDIX B

MEMBERSHIP:
DATA ANALYSIS PANEL

Membership: Data Analysis Panel

M. J. McNally, Leader	Mobil Research and Development Corp.
J. D. Benson	General Motors Research Laboratories
J. C. Callison	Amoco Oil Company
J. P. Graham	Chevron Research and Technology Co.
T. Wusz	Unocal

APPENDIX C

TEST FUEL PROPERTIES

TABLE C-1

SUPPLIERS' FUEL INSPECTIONS

1985/1986 FBRU FUELS

	Low-Octane Base Blend RMFD 356-85/86	Intermediate-Octane Base Blend RMFD 357-85/86	High-Octane Base Blend RMFD 358-85/86
Laboratory Inspection			
Distillation, °F			
IBP	91	93	94
10% Evap.	120	124	126
30% Evap.	153	154	186
50% Evap.	195	198	238
70% Evap.	230	251	255
90% Evap.	313	337	291
End Point	388	399	377
Gravity, °API	67.0	62.8	52.3
RVP, psi	8.6	7.6	8.1
Lead, g/gal.	<0.03	<0.03	<0.03
Oxidation Stab., hr.	>24	>24	>24
Hydrocarbon Type, Vol. %			
Aromatics	22	27	55
Olefins	5	10	1
Saturates	73	63	44
Research Octane Number	76.6	90.3	103.5
Motor Octane Number	72.7	82.0	92.3
Sensitivity	3.8	8.3	11.2

TABLE C-2

SUPPLIERS' FUEL INSPECTIONS

1987/1988 FBRU FUELS

	Low-Octane Base Blend RMFD 362-87/88	Intermediate-Octane Base Blend RMFD 363-87/88	High-Octane Base Blend RMFD 364-87/88
Laboratory Inspection			
Distillation, °F			
IBP	98	90	92
10% Evap.	137	124	122
30% Evap.	166	163	185
50% Evap.	192	214	237
70% Evap.	230	272	259
90% Evap.	333	353	294
End Point	413	421	388
RVP, psi	7.2	8.4	8.1
Lead, g/gal.	0.000	0.000	0.000
Oxidation Stab., min.	1440+	1440+	1440+
Hydrocarbon Type, Vol. %			
Aromatics	19.8	27.5	51.3
Olefins	13.8	9.6	0.0
Saturates	66.4	62.7	48.7
Research Octane Number	79.2	90.8	103.5
Motor Octane Number	74.7	82.6	91.8
Sensitivity	4.5	8.2	11.7

APPENDIX D

PROGRAM

COORDINATING RESEARCH COUNCIL
INCORPORATED
219 PERIMETER CENTER PARKWAY
ATLANTA, GEORGIA 30346
(404) 396-3400

Not to be Published

PROGRAM FOR QUANTIFYING PERFORMANCE OF KNOCK SENSOR-EQUIPPED VEHICLES WITH VARYING OCTANE LEVEL

(CRC Project No. CM-124-86)

Prepared by the
Octane Technology and Test Procedures Group
of the
Coordinating Research Council, Inc.

March 1986

TABLE OF CONTENTS

I. OBJECTIVE

The objective of this program is to investigate the possible performance impact of fuels of varying octane quality on knock sensor-equipped vehicles.

II. INTRODUCTION

Modern gasoline engines have been designed with various types of control systems to continuously monitor and control certain parameters such as fuel flow (air/fuel ratio), spark timing, and EGR rates. A great number of these systems employ knock sensors to detect when the engine begins to detonate; this information is used in the control strategy to vary the required parameter to eliminate the detonation. On vehicles with such systems, this leads to changes in acceleration, driveability, and fuel economy. Thus, the traditional measure of fuel octane quality, audible spark knock, may no longer sufficiently describe a fuel's quality and, specifically, a customer's assessment of posted octane quality. This program, therefore, will attempt to quantify the response of various typical knock sensor-equipped vehicles to both knocking and non-knocking fuels. This information may then be used to develop a program to determine customer response to fuel octane quality with these systems.

III. SCOPE

Individual laboratories will determine vehicle response to fuel quality by testing two or more vehicles each. Octane requirement will be determined for each vehicle; fuel economy, driveability, and acceleration performance will be measured on both knocking and non-knocking fuels.

IV. FUELS

This program will use 1984 or 1985 full-boiling range unleaded (FBRU) reference fuels. The fuels were chosen to approximate anti-knock indices of 84, 87, 92, and 95 (actual values are 87, 91, 97, and 100 RON). This will ensure that vehicles with either high or low octane requirement may be tested with at least one knocking and one non-knocking fuel.

V. TEST VEHICLES

The test vehicles will include as many different engine/control systems as possible that include knock sensors. They will include both manual and automatic transmissions; normally aspirated and turbocharged; carburetted and fuel injected; and with and without air conditioning. The program is expected to include a minimum of fifteen vehicles. It will include, but not be limited to, those listed in Attachment 1. All cars must have accumulated 6,000 miles; they must be in good working order, and be adjusted to vehicle manufacturer's specifications.

VI. DATA REPORTING

All data should be recorded on the data forms provided in Attachment 2. The original data forms should be sent to:

Mr. Charles Sherwood
Ford Motor Company
Engine & Electrical Engineering Building
21500 Oakwood Boulevard
Room E097
Dearborn, Michigan 48121-2053

A copy of the letter of transmittal should be sent to:

Coordinating Research Council, Inc.
219 Perimeter Center Parkway
Suite 400
Atlanta, Georgia 30346

VII. TEST PROCEDURE

Testing will proceed in four steps, including:

- Determining octane number requirement,
- Determining acceleration performance,
- Measuring fuel economy, and
- Rating driveability.

Testing should include all fuels in the test set. Although the tests may be run in any convenient order, it is recommended that the E-15-85 Technique be run first to make sure that the test vehicle has neither an extremely high or low requirement. Test vehicles should be chosen to assure that both knocking and non-knocking tests result from using this test fuel set; this will tend to maximize differences in vehicle response to the procedures and thus allow easier quantification of these differences. During all phases of testing, the rater should note any knock and its intensity, and note any driveability problems. Except for the E-15-85 Technique, all tests should be replicated as required to assure accurate results. Testing may be performed on the road or chassis dynamometer at the discretion of the individual laboratory. Tests should be conducted on level roads, with back-to-back tests conducted as closely together as possible to negate any weather effects. Tests will be conducted on moderately dry days, preferably at ambient temperatures between 60°F (15.5°C) and 90°F (32.2°C). Tests should not be conducted during periods of high humidity such as prevail when rain is threatening or during or immediately after a rain storm. Laboratories with control capabilities should target for 70°F (21°C) air temperature and 50 grains of water per pound (7.14 gm/kg) of dry air, whenever possible.

A. Octane Number Requirement

Both the maximum and minimum octane number requirement of all vehicles should be determined using the CRC E-15-85 Technique (Attachment 3) to ensure that the vehicle will fit within the test fuel set. The requirements should be determined at both maximum and part-throttle in each gear evaluated.

B. Acceleration

Measurement of vehicle acceleration should be made using the SAE J1491 Technique (which is proposed as an SAE Recommended Practice) presented in Attachment 4. Both 0-60 mph and 40-60 mph accelerations should be measured. All 0-60 mph accelerations should be run at wide-open-throttle (WOT) as specified in Sections 8.2 and 8.3 of the Technique. The 40-60 mph accelerations should be run as specified in Section 8.4, with the exception that automatic transmissions should be run twice, allowing the transmission to downshift/disengage converter clutch in one case, and holding at detent/converter clutch engaged in 3rd gear in the other case. To assure that the engine remains stabilized during testing, coolant temperature should be monitored or vehicle should be run at 45-55 mph for a short period of time between accelerations to allow restabilization. All accelerations should be commenced 5-10 mph below speed at which timing begins to allow the correct throttle position to be obtained during the time measurements.

C. Fuel Economy

Fuel economy measurement should be made using the SAE J1082 Road Test Procedure (Attachment 5). All four driving cycles should be performed. Replicate tests must be made to meet repeatability guidelines. Fuel economy must be corrected using the formula listed in Section 10.2.2. Correction factor C_4 for fuel temperature should be taken from Table 1 using Group 3 figures.

D. Driveability

Driveability ratings will be made using the CRC Cold-Start and Warmup Driveability Procedure (Attachment 6). Prior to rating, the vehicle should be warmed-up by driving a minimum of twenty miles at 55 mph. The rating procedure will entail running Steps F through L, inclusive.

Attachment 1

PROPOSED
TEST VEHICLES

1984

3.8L Turbo	Buick Regal
5.2L	Chrysler New Yorker
2.3L Turbo	Mercury Cougar
3.8L	Mercury Capri

1985

1.7L	AMC Alliance
3.0L	Buick
3.8L	Buick
5.0L	Chevrolet Pick-Up
2.2L	Dodge Shelby Charger
2.3L Turbo	Mercury Merkur
1.8L Turbo	Pontiac Sunbird
2.2L Turbo	Plymouth Lancer
1.8L	Volkswagen GT1

1985 CRC OCTANE NUMBER REQUIREMENT SURVEY - 1985 MODEL VEHICLES

Company ______________ Test Location: Road ________ Chassis ________ Sheet _____ of _____ Sheets

For detailed questions contact: Name ______________________ Date __________

Telephone ______________ Driver ______________ Observer ______________

Vehicle Make ____________ Model ____________ No. of Cyl. ____________ Engine Cal. (Ford) ____________

V.I.N. ______________________ License No. ______________________

Converter Clutch Application

Vacuum ______________________

MPH ______________________

Transmission Downshift Characteristics		
MPH	RPM	Man. Vac.
25		
35		
45		
55		

Road Load			
MPH	VAC	MPH	VAC
25		45	
35		55	

TO BE FILLED IN BY CRC			VEHICLE												WEATHER					TANK FUEL DATA	
Obs. No.	Lab Code	Vehicle Code	Emission Cert. (1)	Induction (2)	Carburetion (3)	Displacement Liters	Knock Sensor (4)	Knock Sensor (5)	Compression Ratio	Transmission (6)	Transmission (7)	Air Cond. (4)	Spark Advance °BTDC (8) As Received	Spark Advance °BTDC (8) As Tested	Odometer Miles	Amb. Temp. °F	Barometer " Hg.	Humidity Gr./Lb.	Card No.	Cust. Knock (9)	Research Octane Number	Motor Octane Number
1 2 3	4 5	6 7 8 9	10	11	12	13 14	15	16	17 18 19	20	21	22	23 24 25	26 27 28	29 30 31 32 33	34 35 36	37 38 39 40	41 42 43	44	45	46 47 48 49	50 51 52 5
																			1			

CARD 1 (CONTINUED)					
RATER T.F. REPORT					FOR USE BY CRC
Knock Intensity (10)	Throttle (12)	Test Gear No.	RPM of Max. Knock Intensity	Man. Vac. " Hg/psig (11)	
54	55	56	57 58 59 60	61 62 63	64 65 66 67 68 69 70 71 72

OCTANE NUMBER REQUIREMENTS											
		MAXIMUM						PART-THROTTLE TECHNIQUE			
Fuel	Card No.	Throttle (12)	Research Octane Number (13)	Test Gear No.	Conv. Clutch (4)	RPM of Maximum Knock Intensity	Man. Vac. " Hg/psig (11)	Research Octane Number (13) (14)	Test Gear No.	RPM of Maximum Knock Intensity	Man. Vac. " Hg/psig (11)
	44	45	46 47 48 49	50	51	52 53 54 55	56 57 58 59	60 61 62 63	64	65 66 67 68	69 70 71
FBRU	2										
FBRSU	3										
PRF	4										

Reference Fuel		Test Gear No.	Man. Vac. " Hg/psig (11)	Max. Knock Intensity (10)			(10)	Speed Range, RPM		RPM of Max. Knock Intensity
				Acceleration						
Series	Res. O.N.			1	2	3	Final Rating	Knock In	Knock Out	

(1) F = Federal; C = California; A = Altitude; B = "C" and "A"

(2) V = Variable Venturi; T = Turbocharged

(3) Number of Carb. Venturis or T for throttle body injection or P for port injection

(4) Y = Yes; N = No

(5) If Column 4 is Y, record H = Higher Req., L = Lower Req. Use second sheet for lower (L) requirement.

(6) A = Automatic; M = Manual

(7) Record number of transmission speeds

(8) Columns 23 and 26: + = BTDC; — = ATDC

(9) Y = Yes; N = No; O = Objectionable

(10) N = None; B = Borderline; A = Above Borderline

(11) Enter plus (+) for Vacuum (" Hg) or minus (—) for boost pressure (psig)

(12) M = Maximum Throttle; P = Part Throttle higher than Maximum Throttle Requirements

(13) Columns 46 and 60: L = Less than lowest available fuel; H = Higher than highest available fuel

(14) If part-throttle requirement is greater than four numbers below maximum throttle requirement, enter letter F in Column 60.

Reference Fuel		Test Gear No.	Man. Vac. "Hg/psig (11)	Max. Knock Intensity (10)			(10)	Speed Range, RPM		RPM of Max. Knock Intensity
				Acceleration						
Series	Res. O.N.			1	2	3	Final Rating	Knock In	Knock Out	

ATTACHMENT 2

LEVEL ROAD W.O.T. ACCELERATION PERFORMANCE
VEHICLE DATA SHEET

Report No._____
Date:_______

Vehicle: Make__________ Model__________ Year_____ Car No.______

Odometer__________ VIN__________

Test Location:__________ Track Orientation:_______

Start of Test: Date__________ Time_______

Completion of Test: Date__________ Time_______

Driver__________ Observer_______

Transmission: Automatic Shift Mode__________ Manual Launch RPM_______

Shift RPM__________

Remarks:

Ambient Conditions for Test:

Dry Bulb Temp._____°F_____°C Wet Bulb Temp._____°F_____°C Relative Humidity_____%

Barometric Pressure_____In.Hg. (kPa) Wind Velocity_____Mph Direction_______

0-30 MPH (Elapsed Time)*

1____ 2____ 3____ 4____ 5____ 6____ Avg.____Sec. Variability____%

0-50 MPH (Elapsed Time)*

1____ 2____ 3____ 4____ 5____ 6____ Avg.____Sec. Variability____%

0-60 MPH (Elapsed Time)*

1____ 2____ 3____ 4____ 5____ 6____ Avg.____Sec. Variability____%

40-60 MPH (Elapsed Time)*

1____ 2____ 3____ 4____ 5____ 6____ Avg.____Sec. Variability____%

0-5 SEC (Distance Covered)*

1____ 2____ 3____ 4____ 5____ 6____ Avg.____Ft. Variability____%

0-5 SEC (Terminal Speed)*

1____ 2____ 3____ 4____ 5____ 6____ Avg.____Mph. Variability____%

1/4 Mile (Elapsed Time)*

1____ 2____ 3____ 4____ 5____ 6____ Avg.____Sec. Variability____%

1/4 Mile (Terminal Speed)*

1____ 2____ 3____ 4____ 5____ 6____ Avg.____Mph. Variability____%

*Times (or speed or distance) should be averaged in Pairs of 1-2, 3-4, 5-6, then collectively averaged. Two valid paired runs are considered adequate. When difficulty is experienced in one run, the pair should be excluded.

LEVEL ROAD W.O.T. ACCELERATION PERFORMANCE
VEHICLE SPECIFICATION SHEET

Report No._____
Date:________

Vehicle: Make__________ Model__________ Year____ Car No.________

Odometer__________ VIN______________

EQUIPPED WITH

Engine: Type________ Displacement________ Compression Ratio________
No. of Cylinders______ Rated SAE Horsepower________
Fuel System________
Engine Fan Type________
Electronic Engine Control Yes___ No___ Knock Sensor Yes___ No___
Idle Speed________ RPM (Drive)________ RPM (Neutral)
Redline________ RPM Initial Timing________

Transmission: Type________
Forward Ratios________

Optional Special Equipment
____
____

Axle Ratio: Front Wheel Drive[1]________
Rear Wheel Drive[2]________

Equipment Removed for Test
____
____

1 Overall Top Gear Ratio = transfer drive ratio x final reduction gear ratio
2 Rear Wheel Drive = rear axle ratio

Tires: Manufacturer________ Model________
Type______ Size______ Ply Rating______
Pressure (cold)________ Front________psi
Rear________psi

Brake Type________
Emission System Type________
Exhaust System Type________
Air Conditioning________

Operational Checklist

Choke Operation________ Brake Drag________
Throttle Operation________ Parking Brake________
Transmission Operation________ Wheel Alignment________

Fluid Level Checklist

Engine Oil________
Battery________
Transmission________
Coolant________
Brake________
Differential________

Test Fuel

Test Fuel Type & Grade________
Gravity API or Specific______ @60°F (15.6C)
Reid Vapor Pressure________psi (kpa)
Distillation 10%________°F (°C)
50%________°F (°C)
90%________°F (°C)
Test Fuel Octane No. RON______ MON______
$\frac{R+M}{2}$________

Test Fuel Cetane No.________

Notes:

24.164

DATA FORM
FUEL ECONOMY TEST—LIGHT DUTY VEHICLES

CAR NO ____________ VIN ____________

YEAR AND MAKE ____________

MODEL AND BODY ____________

ENGINE TYPE ____________ DISP. ____________

DRIVE AXLE RATIO ____________

TRANSMISSION ____________

TIRE MAKE ____________ SIZE ____________

TIRE PRESSURE: F ____________ R ____________

FUEL TYPE ____________ SPECIFIC GRAVITY ____________

TEST VEHICLE WEIGHT ____________

TEST ROAD ____________

TYPE OF SURFACE ____________

INSTRUMENTATION

1. ____________ NO ____________

2. ____________ NO ____________

3. ____________ NO ____________

4. ____________ NO ____________

URBAN CYCLE (2.00 mile) (3.22 km) DATE ____________ TIME ____________

ODOMETER: START ____________ FINISH ____________

DIRECTION	FUEL TEMPERATURE 0.5 (0.8)	1.0 (1.6)	1.5 (2.4)	2.0 (3.2)	mile km	ACCUM. TIME	ACCUM. FUEL	AMBIENT CONDITIONS TEMPERATURE START	FIN	BAROMETRIC START	FIN	WIND START	FIN

SUBURBAN CYCLE (5.2 mile) (8.37 km) DATE ____________ TIME ____________

ODOMETER: START ____________ FINISH ____________

DIRECTION	FUEL TEMPERATURE 2.0 (3.2)	3.3 (5.3)	5.2 (8.4)	mile km	ACCUM. TIME	ACCUM. FUEL	AMBIENT CONDITIONS TEMPERATURE START	FIN	BAROMETRIC START	FIN	WIND START	FIN

____________ mile/h (km/h) INTERSTATE CYCLE (4.7 miles) (7.56 km) DATE ____________ TIME ____________

ODOMETER: START ____________ FINISH ____________

DIRECTION	FUEL TEMPERATURE (0.0) (0.0)	(4.7) (7.6)	mile km	ACCUM. TIME	ACCUM. FUEL	AMBIENT CONDITIONS TEMPERATURE START	FIN	BAROMETRIC START	FIN.	WIND START	FIN

TESTED BY ____________

SUMMARY SHEET
FUEL ECONOMY TEST DATA—LIGHT DUTY VEHICLES

DATE ____________

VEHICLE MAKE ____________ ENGINE ____________ CAR NO. ____________

VIN ____________ TRANSMISSION ____________ AXLE RATIO ____________

TIRE MAKE ____________ SIZE ____________ PRESSURE ____________

VEHICLE TEST WEIGHT ____________

TEST ROAD ____________ SURFACE ____________

FUEL ECONOMY*

	CORRECTED* mile/gal (km/L)	OBSERVED mile/gal (km/L)	FUEL TEMP °F (°C)	AIR TEMP °F (°C)	BARO PRESS. in Hg (kPa)	WIND SPEED-DIRECTION mile/h (km/L)
URBAN CYCLE						
SUBURBAN CYCLE						
55 mile/h (89 km/h) INTERSTATE CYCLE						
70 mile/h (113 km/h) INTERSTATE CYCLE						

*Cross out those units not used

*The Corrected Fuel Economy may be expressed in terms of fuel as consumed litres per 100 km

COMMENTS ____________

TESTED BY ____________

FUEL ECONOMY TEST—LIGHT DUTY VEHICLES
TEST VEHICLE SPECIFICATIONS AND PREPARATION

SPECIFICATION LIST

DATE ____________
CAR NO ____________
YEAR AND MAKE ____________
MODEL AND BODY ____________
VEHICLE IDENT NO ____________
PRODUCTION ____________ OTHER ____________
ENGINE TYPE ____________ DISP ____________
NET hp (U S ____________ COMP RATIO ____________
ENGINE NO ____________
ENGINE EMISSION CALIBRATION NO ____________
CARB TYPE AND NO ____________
DISTRIBUTOR NO ____________
EXHAUST SYSTEM TYPE ____________
TRANSMISSION ____________

DRIVE AXLE TYPE AND RATIO ____________
BRAKES (DISC OR DRUM) F ____________ R ____________
STEERING ____________
*TIRE MAKE ____________ SIZE ____________
LOAD RANGE ____________ TYPE ____________
% TREAD ____________
COLD INFLATION—TIRE PRESSURE
LF ____________ RF ____________
LR ____________ RR ____________
TEST WEIGHT ____________
*TIRES MUST HAVE A MINIMUM OF 100 mile (160 km) BREAK-IN ON ROAD OR TRACK

CHECK LIST

_____ ENGINE OIL LEVEL OK
_____ COOLANT LEVEL OK
_____ TRANSMISSION FLUID LEVEL OK
_____ BELTS AND HOSES—TIGHT
_____ EMISSION CONTROLS—FUNCTIONAL
_____ CHOKE OPERATION—FUNCTIONAL
_____ THROTTLE OPERATION—FUNCTIONAL
_____ PUMP AND NOZZLES—NO LEAKS
_____ IGNITION WIRES—TIGHT
_____ BRAKE DRAG—NOT EXCESSIVE
_____ TRANSMISSION OPERATION
_____ TIRE PRESSURE AND CONDITION
_____ ENGINE TUNE—PERFORMED
_____ IGNITION TIMING ____________

_____ IDLE rpm ____________ IDLE CO ____________
_____ IGNITION POINT DWELL ____________
_____ WHEEL ALIGNMENT—PERFORMED
_____ AIR CLEANER—CLEAN

_____ A/C COMPRESSOR LOAD—REMOVED
_____ NO FUEL LEAKS
_____ MANIFOLD HEAT VALVE—FUNCTIONAL
_____ FAN CLUTCH—FUNCTIONAL

$$\%\ \text{TREAD} = \frac{\text{AVERAGE TREAD DEPTH OF TEST TIRES}}{\text{AVERAGE TREAD DEPTH OF IDENTICAL NEW TIRE}} \cdot 100$$

EQUIPPED WITH OPTIONAL EQUIPMENT

_____ POWER BRAKES
_____ POWER STEERING
_____ AIR CONDITIONING
_____ RADIO
_____ POWER SEATS
_____ POWER WINDOWS
_____ POWER DOOR LOCKS
_____
_____
_____
_____

COMMENTS: ____________

CAR CHECKED BY: ____________

DATE: ____________

TEST FUEL SPECIFICATIONS
FUEL TYPE AND GRADE ____________
GRAVITY (API OR SPECIFIC) ____________ AT 60°F (15.6°C)
REID VAPOR PRESSURE ____________ psi (kPa)
DISTILLATION 10% ____________ °F or °C
50% ____________ °F or °C
90% ____________ °F or °C

CRC driveability data sheet

Card	Run No	Car	Fuel	Rater	Date	Time	Temperatures: Soak	Temperatures: Run	Starting Time, sec.: Initial	Restart 1	Restart 2	Restart 3	Idle N.: Ruf Stalls	Idle Dr.: Ruf Stalls
1	2 3 4	5 6 7	8	9	10 11 12	13 14 15 16	17 18	19 20	21 22 23	24 25 26	27 28 29	30 31 32	33 34 35	36 37 38

Card 2 — Run No. (1 2 3 4)

0.0 0-25 Lt. Th. (Stalls Ac Dc)	0.1 25 Cruise (Stalls Ac Dc)	0.2 25-35 Detent (Stalls Ac Dc)	0.3 0-35 WOT (Stalls Ac Dc)	0.4 10-25 Lt. Th. (Stalls Ac Dc)	0.5 Idle (Ruf Stalls)
39 40 41 42 43 44	45 46 47 48 49 50	51 52 53 54 55 56	57 58 59 60 61 62	63 64 65 66 67 68	69 70
0.5	0.6	0.7	0.8	0.9	1.0
5 6 7 8 9 10	11 12 13 14 15 16	17 18 19 20 21 22	23 24 25 26 27 28	29 30 31 32 33 34	35 36
1.0	1.1	1.2	1.3	1.4	1.5
37 38 39 40 41 42	43 44 45 46 47 48	49 50 51 52 53 54	55 56 57 58 59 60	61 62 63 64 65 66	67 68

Card 3 — Run No. (1 2 3 4)

1.5 0-45 Crowd (Stalls Ac Dc)	1.9 25-35 Detent (Stalls Ac Dc)	2.0 0-35 WOT (Stalls Ac Dc)	2.1 10-25 Lt. Th. (Stalls Ac Dc)	2.2 Idle (Ruf Stalls)
5 6 7 8 9 10	11 12 13 14 15 16	17 18 19 20 21 22	23 24 25 26 27 28	29 30
2.2	2.6	2.7	2.8	2.9
31 32 33 34 35 36	37 38 39 40 41 42	43 44 45 46 47 48	49 50 51 52 53 54	55 56

Card 4 — Run No (1 2 3 4)

2.9	3.3	3.4	3.5	3.6	C for Comment
5 6 7 8 9 10	11 12 13 14 15 16	17 18 19 20 21 22	23 24 25 26 27 28	29 30	31
3.6	4.0	4.1	4.2	4.3	
4.3	4.7	4.1	4.1	5.0	

Comments:

TECHNIQUE FOR DETERMINATION
OF OCTANE NUMBER REQUIREMENTS
OF LIGHT-DUTY VEHICLES

(CRC Designation E-15-85)

September 1984

TECHNIQUE FOR DETERMINATION OF OCTANE NUMBER REQUIREMENTS OF LIGHT-DUTY VEHICLES

(CRC Designation E-15-85 - Including \nnex A)

A. GENERAL

The technique provides for the determination of maximum octane number requirements (and minimum octane number requirements for vehicles equipped with knock sensors), whether at maximum-throttle or part-throttle, of a vehicle in terms of borderline spark knock on two series of full-boiling range reference fuels as well as on primary reference fuels. If the maximum requirement is at maximum-throttle, then part-throttle requirements are investigated with only FBRU fuels of up to, and including, four octane numbers lower than the maximum requirement. It also provides octane requirements throughout the speed range on primary reference fuels.

Spark knock of tank fuel will also be determined.

B. DEFINITION OF TERMS

The following definitions of knock, approved by the CLR and CFR Committees on June 8, 1954, have been rephrased for clarification and adaptability to current technology by the Survey Steering Panel.

1. **Spark Knock:**

   Spark knock is the noise associated with autoignition* of a portion of the fuel-air mixture ahead of the advancing flame front. It is recurrent and repeatable in terms of audibility and fuel octane quality.

2. **Knock Intensity**

   a. Borderline Knock

   This means spark knock of lowest audible intensity of at least three (3) pings, and over a range of engine speed of at least 50 rpm, all being repeatable during subsequent accelerations.

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* Autoignition: The spontaneous ignition and the resulting very rapid reaction of a portion or all of the fuel-air mixture. The flame speed is many, many times greater than that which follows normal spark ignition. There is no time reference for autoignition.

b. No Knock

This means either no audible knock or less than borderline knock.

c. Above Borderline Knock

This means spark knock of greater than borderline intensity.

3. Octane Number Requirements

a. Maximum Requirement

This is equivalent to the octane number of the highest reference fuel giving borderline knock as previously defined (the next highest fuel gives no knock). If the knock intensity with the highest fuel giving knock is above borderline, the maximum requirement shall be equivalent to the mid-point between the octane number of the fuel giving knock and that of the next highest fuel which gives no knock.

b. Minimum Requirement (for vehicles with knock sensors)

This is equivalent to the octane number of the lowest reference fuel giving borderline knock (the next lower fuel will give above borderline knock).

4. Definition of Accelerations

Accelerations are made at maximum-throttle and part-throttle conditions which are defined below:

a. Maximum-Throttle

The throttle is depressed and held at either full-throttle or the widest throttle position that does not cause the transmission to downshift (detent) throughout the acceleration in each of the required test gears listed in D.3.d.(1)(a). The detent manifold vacuum/pressure obtainable on a given model is determined by the transmission characteristics. For manual transmissions, the throttle is depressed fully throughout the acceleration.

b. Part-Throttle

The throttle is depressed and regulated throughout the acceleration to maintain a desired, constant critical manifold vacuum as defined in D.3.d.(1)(d).

C. VEHICLE PREPARATION

The following vehicle preparation steps should be completed before any octane tests are run. Detailed procedures for each adjustment can be found in the manufacturers' shop manuals.

1. Record vehicle identification number and emission control type, Federal, Altitude, or California. Fill in heading on data sheet DFMF-11-1185. For knock sensor-equipped vehicles, two DFMF-11-1185 data sheets should be filled out completely: one for maximum requirement, and one for minimum requirement. Ford emission calibration numbers are to be recorded.

2. Inspect all vacuum lines and air pump hoses for appropriate connections. Also, check to see if PCV valve, spark advance vacuum delay controls, EGR valve, knock sensors, and heated inlet air mechanism are functioning. Engine must be warmed up for these checks.

3. Record engine idle speed and observe anti-dieseling solenoid operation. Adjust to manufacturers' recommended specifications as specified on the under-hood decal.

4. Observe and record basic spark timing at recommended engine speed. Adjust to manufacturers' recommended setting as specified on the under-hood decal.

5. Crankcase oil, radiator coolant, automatic transmission fluid, and battery fluid levels shall be maintained as recommended by the manufacturer.

6. A calibrated tachometer graduated in 100 rpm (or smaller) increments and capable of indicating engine speed from 0-5000 rpm shall be installed on each vehicle.

7. One calibrated vacuum gage, graduated in one-half inch of mercury (or smaller) increments and capable of indicating vacuum from 0-24 inches of mercury (0-81 kPa) shall be connected to the intake manifold. For vehicles with turbochargers, a compound vacuum/pressure gage should be used; the pressure side of the gage should be capable of indicating pressures up to 15 psi (103 kPa).

8. An auxiliary fuel system shall be provided to supply test fuels to the engine. Caution shall be taken to avoid placing auxiliary fuel lines in locations which promote vapor lock. If vehicles with carbureted engines have tank return fuel lines, this return line should be blocked off. Disconnect fuel tank vent line at evaporation control system canister. Instructions for fuel handling with fuel injection systems are given in Annex A.

9. For vehicles with owner questionnaire completed, a sample of the tank gasoline shall be withdrawn for determination of Research and Motor method octane number ratings. If insufficient fuel is available, omit this step and obtain tank fuel observations as described in Item D.3.d.(2).

D. TEST PROCEDURE

1. Engine Warm-Up

a. To stabilize engine temperatures, a minimum of ten miles of warm-up is required. The test vehicle should be operated at 55 mph (88 kph) in top gear with a minimum of full-throttle operation.

b. During the warm-up period, the general mechanical condition of the vehicle should be checked to insure satisfactory and safe operation during test work.

2. Fuel Changeover

Caution: Because of the installation of catalytic devices on these vehicles, permanent damage may result if the engine runs lean or stalls. Therefore, changeover from one fuel to another must be accomplished without running the carburetor or fuel injection system dry. Fuel handling procedures for vehicles equipped with fuel injection systems are explained in Annex A.

To eliminate contamination of the new fuel with residual amounts of the previous fuel, flush system twice with new fuel.

After fuel changeover, make one maximum-throttle acceleration before beginning Vehicle Rating Procedure.

3. Details of Observations

a. Operating Conditions

All octane number requirements will be determined under level road acceleration conditions.

Tests will be conducted on moderately dry days, preferably at ambient temperatures between 60°F (15.5°C) and 90°F (32.2°C). Tests should not be conducted during periods of high humidity such as prevail when rain is threatening or during or immediately after a rain storm. Laboratories with control capabilities should target for 70°F (21°C) air temperature and 50 grains of water per pound (7.14 gm/kg) of dry air whenever possible.

Air-conditioned vehicles will be tested with air conditioner turned ON. (Normal setting, minimum temperature, low fan.) Air conditioner will be ON at all times.

b. Order of Fuel Testing

1) Tank
2) FBRSU
3) FBRU
4) Primary

c. Determination of Knock Intensity

Maximum octane requirements will be established by evaluating the occurrence of knock in terms of knock intensity: "N" for none, "B" for borderline, and "A" for above borderline. Establishment of representative knock intensity for a given fuel will be accomplished with a maximum of three (3) rated accelerations. Coastdown time between the end of one acceleration and the beginning of the next should be approximately twenty (20) seconds. As defined below, the first two duplicating accelerations are sufficient with "N" and "B" intensity.

Acceleration Number 1	2	3	Representative Rating
N	N	-	N
N	B	N	N
N	B	B	B
B	N	B	B
B	B	-	B
B	A	-	A
A	-	-	A

All subsequent accelerations will normally be discontinued when "A" knock intensity is experienced, and testing continued with a higher octane number fuel in that series. An exception will be made if "A" knock is experienced on the highest octane fuel which knocks in the engine. In this case, it may be necessary to run additional accelerations to determine the speed of maximum knock intensity. If "A" knock is experienced at initiation of acceleration, as limited by transmission characteristics, this speed will be considered the speed of maximum knock. Otherwise, the midpoint between knock-in and knock-out will be considered the speed of maximum knock. When establishing knock-in and knock-out, back off on the throttle between points to eliminate "A" knock.

Minimum octane number requirements (for vehicles equipped with knock sensors) will be established in a similar manner except that when "A" knock intensity is encountered, subsequent accelerations will be made with a given fuel until duplicate "A" ratings are obtained over a measurable range of engine speeds as indicated below:

Acceleration Number			Representative Rating
1	2	3	
B	A	B	B
B	A	A	A
A	A	-	A
A	B	B	B

d. Determination of Octane Requirements

Tests should be run to 60 mph (97 kph) unless required to terminate at 55 mph (88 kph) because of legal speed limits.

(1) Vehicle Operating Procedure

(a) Establishment of Automatic Transmission Characteristics (for Maximum-Throttle Accelerations)

Obtain the transmission downshift characteristics of engine rpm and manifold vacuum/pressure at 25, 35, 45, and 55 mph (40, 56, 72, and 88 kph) incremental speeds (as obtainable in each gear), by movement of the throttle through the detent, i.e., downshift, throttle position. Also determine the minimum attainable road speed. These characteristics are to be determined for each of the gears specified in the table below. For transmissions with converter clutches, determine the minimum road speed for clutch application. At this initial speed and at 10 mph (16 kph), increments up to about 60 mph (97 kph) determine minimum vacuums (pressures) for application. Record all road speed/engine rpm/vacuum or pressure measurements from above on data sheet.

Do not use brakes, turn signals or hazard flashers during accelerations as these may affect electronic engine controls.

The selection of required test gears, and test gear/converter clutch combinations (if applicable) for various types of transmissions are listed below. Transmissions not explicitly described should be tested in a manner as similar as possible to those listed. Automatic transmission vehicles should be tested with the gear selector in D or O.

TRANSMISSION GEAR SELECTION

AUTOMATICS

Place the selector in "D" or "O" and check for critical condition.

Type	Gears to be Tested
GM 4-speed	4th gear, converter clutch engaged 3rd gear, converter clutch disengaged 2nd gear, converter clutch disengaged
GM 3-speed	3rd gear, converter clutch engaged 3rd gear, converter clutch disengaged 2nd gear, converter clutch disengaged
Ford 4-speed overdrive	4th gear 3rd gear 2nd gear
Other 3-speed	3rd gear 2nd gear

MANUALS

5-speed	4th and 3rd gears
4-speed	4th and 3rd gears
3-speed	3rd and 2nd gears

(b) Maximum-Throttle Accelerations - Automatic Transmissions

For maximum-throttle accelerations in each of the gears and gear/converter clutch combinations specified above, accelerate at the detent/application condition according to the speed versus vacuum/pressure profiles determined in (a) from the minimum obtainable speed up to 60 mph (97 kph). If the transmission downshifts, abort and start the acceleration again. Start with the highest gear or gear/clutch combination and proceed in descending order.

(c) Maximum-Throttle Accelerations - Manual Transmissions

Select the highest gear as specified in the table above. Start at the lowest speed from which the vehicle will accelerate smoothly or 30 mph (48 kph), whichever is higher, and depress the throttle full throughout the acceleration up to 60 mph (97 kph).

Select the next lower gear specified in the table above and accelerate at full throttle from the minimum speed from which the vehicle will accelerate smoothly up to 60 mph (97 kph).

(d) Part-Throttle Accelerations (Both Automatic and Manual Transmissions)

Select the highest gear up to the minimum vehicle speed at which the converter clutch will engage, and the highest gear/converter clutch combination above this minimum speed, to obtain the critical part-throttle vacuum or pressure. To obtain the critical part-throttle vacuum/pressure, first operate at road load (constant speed), at 25, 35, 45, and 55 mph (40, 56, 72, and 88 kph) incremental speeds (if obtainable in the specified gear). At each speed, move the throttle (in 3 to 5 seconds) from the road-load vacuum to:

1. one inch Hg (3.4 kPa) above full-throttle vacuum for manual transmissions;

2. one inch Hg (3.4 kPa) above detent vacuum for automatic transmissions without converter clutches;

3. one inch Hg (3.4 kPa) above the minimum vacuum at which the converter clutch disengages for so-equipped automatic transmissions.

The vehicle brakes may be applied lightly, if necessary, to maintain vehicle speed during throttle fanning, except for vehicles with converter clutch transmissions or EGR cut-outs.

If knocking occurs within any of the vacuum/pressure ranges, establish the manifold vacuum/pressure which gives maximum knock intensity on each fuel series. This is the critical vacuum/pressure to be used for all subsequent constant-vacuum/pressure part-throttle accelerations from the minimum obtainable speed in the test gear to 60 mph (97 kph), or until the vehicle ceases to accelerate. This critical vacuum/pressure should be determined for each reference fuel series.

(2) Tank Fuel Observations on Vehicles with Owner's Questionnaire

Investigate for maximum-throttle and part-throttle knock as detailed in Item 3d(1). Define maximum knock intensity as per Item 3c. Record maximum knock intensity, speed of maximum knock intensity, and manifold vacuum/pressure at each operating condition.

(3) Vehicle Rating Procedure (for Rater)

Knock rating should be performed while in a normal seated position (head above instrument panel) with floor mats in place.

Step 1 - After Tank Fuel Observations, use a fuel estimated to give borderline knock in a given fuel series and investigate for incidence of knock under conditions as described in D.3.d.(1)(b) above, and D.3.d.(1)(c) above, whichever is applicable.

Step 2 - If no knock occurs, go to a lower octane number blend in that series and repeat Step 1.

Step 3 - If knock occurs at one or more of the operating conditions in Step 1, continue investigation at the critical condition(s) with higher octane blends until highest octane fuel giving knock is determined within one octane number or one blend (the next highest fuel gives no knock). Record maximum knock intensity on all fuels. Record speed of maximum knock intensity and manifold vacuum (pressure) on highest octane fuel that knocks.

Step 4 - Using the lowest octane blend that did not knock in Step 3, investigate for incidence of part-throttle knock as described in D.3.d.(1)(d). If knock occurs, continue investigation at critical vacuum/pressure until requirement is defined. Record maximum knock intensity and critical manifold vacuum/pressure on all fuels, and speed of maximum knock intensity on highest octane fuel that knocks.

Step 5 - With FBRU fuel only, if no knock occurs in Step 4, go to a lower octane number blend and repeat Step 4. Discontinue part-throttle investigation if knock is not observed with a fuel four octane numbers lower than determined in Step 3.

Step 6 - For knock sensor-equipped vehicles after determination of maximum requirement, continue with lower octane blends until the lowest octane fuel giving borderline knock is determined.

The rating procedure is given in arrow diagram form on page D-23 for maximum requirement, and on page D-24 for minimum requirement, for knock sensor-equipped cars.

(4) Octane Number Requirement Over Speed Range

Octane requirements over the speed range will be obtained on primary reference fuels only, using throttle position for maximum requirements. These will be established by recording the knock-in and knock-out points during maximum requirement accelerations with each incremental fuel investigated. It may be necessary to test one or two additional lower octane fuels to describe the knocking characteristics over the speed range. Accelerate at maximum requirement throttle position from minimum obtainable speed as determined in 3d(1)(a), up to 3750 rpm, if necessary, in order to define requirements. These should be run to 60 mph (97 kph) unless required to terminate at 55 mph (88 kph) because of legal speed limits. If 3750 rpm cannot be attained in top gear, accelerations shall be discontinued and resumed in the next highest gear from 500 rpm below the engine speed at which top gear accelerations were determined.

When "A" knock is experienced, continue the acceleration, but back off on the throttle to maintain "B" knock until just prior to the knock-out point.

E. INTERPRETATION OF DATA

The data will be recorded on data sheet DFMF-11-1185. For knock sensor-equipped vehicles, two DFMF-11-1185 data forms should be filled out completely: one for maximum requirement, and one for minimum requirement. Octane requirements for all reference fuels shall be determined as follows:

1. If the knock intensity of the highest reference fuel giving knock is borderline, the requirement shall be reported as the octane number of that fuel.

2. If the knock intensity of the highest fuel giving knock is above borderline, the requirement shall be reported as the mid-point between the octane number of the fuel giving knock and that of the next highest fuel.

3. If the octane requirement in high gear is equal to the requirement in a lower gear, report the highest gear data.

4. For part-throttle requirements, report the data from the critical manifold vacuum/pressure observations.

5. For knock sensor-equipped vehicles, report the highest and lowest fuel giving borderline knock.

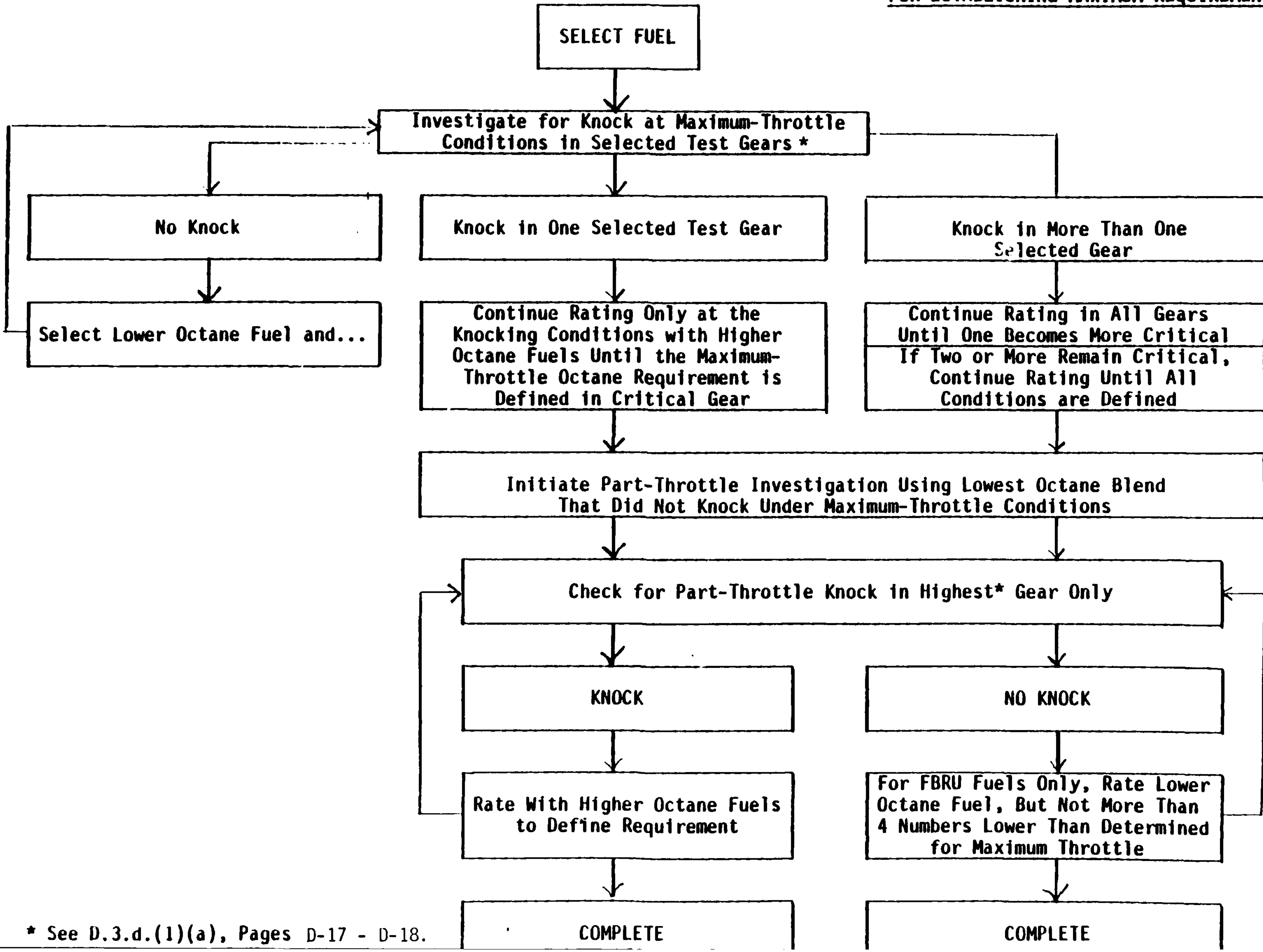
Speed range data shall be reported on data sheet DFMF-11-1185 as the engine speed of knock-in and knock-out for the octane number of the primary reference fuel tested.

Record data on all fuels tested, even though knock was not encountered. When transferring data to the summary block, record the higher requirement, either part-throttle or maximum-throttle condition for all fuels. If the higher requirement is part-throttle, record the part-throttle FBRU requirement in both the maximum and part-throttle columns. If part-throttle and maximum-throttle requirements are equal on FBRU fuels, record the maximum-throttle data in the maximum-requirement columns and the part-throttle data in the part-throttle columns. Use proper letter designation (see footnotes on data sheet) to designate requirements outside of the reference fuel limits or FBRU part-throttle requirement more than four numbers below maximum.

Requirements for the various engine speeds will be determined by fitting a smooth curve through the knock-in and knock-out points on work form DFMF-12-1185. Primary reference fuel requirements at various engine speeds should be reported to the nearest one-half octane number and recorded on the speed range summary block.

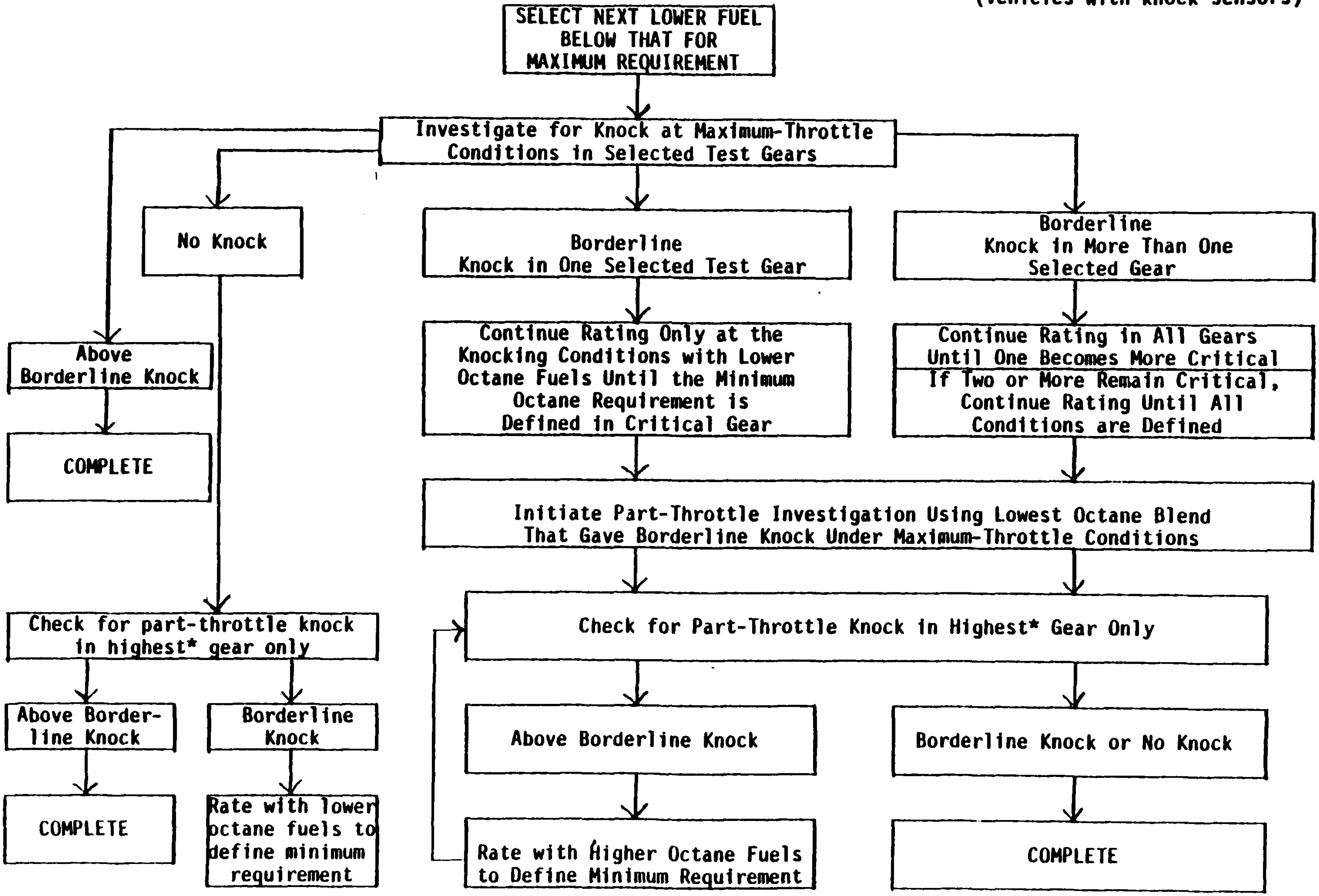
It is important that the vehicle identification number (VIN) of each vehicle tested be recorded on all data sheets to provide a means of cross-indexing.

FOR ESTABLISHING MAXIMUM REQUIREMENTS



* See D.3.d.(1)(a), Pages D-17 - D-18.

FOR ESTABLISHING MINIMUM REQUIREMENTS
(Vehicles with knock sensors)



* See D.3.d.(1)(a), Pages D-17 - D-18.

ANNEX A

TO THE CRC E-15-85 TECHNIQUE

PROCEDURE FOR SETTING UP VEHICLES AND HANDLING REFERENCE FUELS -- VEHICLES EQUIPPED WITH MULTIPLE-PORT FUEL INJECTION

1. To run octane requirements on fuel-injected vehicles it is necessary to run an external fuel line to the inlet of the vehicle fuel injection pump.

2. The fuel return line from the engine to the fuel tank must be disconnected after the fuel pressure regulator (in engine compartment) and before the fuel tank. An auxiliary line long enough to reach the cans must be added to the fuel return line.

3. Make certain that the fuel tank connections are plugged; this means both the normal fuel pump inlet line and the normal fuel return line connection. On vehicles with an in-tank booster pump, this pump must be shut off so it cannot run during the time the vehicle is operating on the external fuel system. If this pump is not disconnected, it will be destroyed.

4. An electric fuel pump (Bendix type acceptable) must be used to draw fuel from the reference fuel can to supply the fuel injection pump on the vehicle. Caution must be exercised to keep the fuel line between the reference fuel cans and the vehicle fuel injection pump full of fuel. If very much air gets into this line, the fuel injection system will become air bound and it is difficult to get the air out of the system.

5. Once the fuel injection pump line and return line have been disconnected, all subsequent operations must be done from an external fuel source.

6. It is possible to use three-way valves in the fuel line between the fuel pump and the fuel tank and between the return line and the fuel tank. When used, the operator must change the return line valve to the auxiliary fuel system while the engine is shut down, to avoid building up excessive pressure in the return line which could damage both the fuel pressure regulator and injection pump.

7. When changing from one reference fuel to another, the following steps must be followed:

   a. Put fuel inlet line in reference fuel tank with the return line going to a slop fuel can. Do not keep fuel inlet line out of the fuel can any longer than is necessary to move it from one can to the next. DO NOT RUN OUT OF FUEL.

b. Observe the fuel stream in the fuel return line. As soon as a steady flow of fuel is observed, move the fuel return line to an empty one-quart can (0.946 ℓ). Allow one quart (0.946 ℓ) of fuel to flow into this can before inserting the return line into the chosen reference fuel can. This operation should take about 60 seconds.

c. When going to the next reference fuel, it will be necessary to repeat Steps a and b.

The fuel injection pumps on most vehicles pump between 30 and 50 gallons (114-189 ℓ/h) of fuel per hour. Therefore, Steps a and b should be folowed very closely or there will be gross reference fuel contamination, or you will use a lot more reference fuel than is required to run each test. If Steps a and b are followed exactly, you will be discarding to slop about two quarts (1.892 ℓ) of reference fuel each time you change reference fuels. The two quarts (1.892 ℓ) to slop will be at least as much fuel as is consumed to obtain the reference fuel rating.

CAUTION

For high-pressure fuel systems, be sure to relieve the pressure before disconnecting fuel lines. Also, use auxiliary fuel lines designed for high pressure. The engine and auxiliary fuel pump should be shut off while changing from auxiliary to tank fuels.

Diagnostic scanners should not be used while knock testing.

Auxiliary hoses should be rated for at least 250 psi working pressure and 1000 psi burst pressure.

PROCEDURE FOR SETTING UP VEHICLES AND HANDLING REFERENCE FUELS -- VEHICLES EQUIPPED WITH THROTTLE-BODY FUEL INJECTION

The General Motors throttle-body fuel injection system is shown in the attached schematic drawing. The fuel supply system consists of an in-tank electric fuel pump, a full-flow fuel filter mounted on the vehicle frame, a fuel pressure regulator integral with the throttle body, fuel supply and return lines, and two fuel injectors. The injection timing and amount of fuel supplied is controlled by an electronic control module (not shown in figure). To prepare a vehicle with this system for octane requirement testing, an auxiliary electric fuel pump must be installed. The fuel pressure regulator controls fuel pressure at the injectors to a nominal 10.5 psi; therefore, an auxiliary pump capable of at least 10.5 psi outlet pressure must be used for satisfactory engine operation. The following procedure is recommended for preparing a vehicle with throttle-body fuel injection for octane requirement testing and for changing reference fuels during such testing:

1. Disconnect and plug the fuel supply and fuel return lines at the locations shown in the figure. Install an additional line between the fuel supply line and the outlet of the auxiliary pump. Connect the inlet of the auxiliary pump to the reference fuel can. Connect the fuel return line to the reference fuel can through a tee at the auxiliary pump inlet. All auxiliary fuel lines are indicated by dashed lines in the figure.

2. An optional arrangement would be to use three-way selector valves in the fuel supply and fuel return lines at the locations where auxiliary fuel lines are connected. When these valves are used, the operator must change the valves to the external fuel system while the engine is shut off to avoid building up excessive pressure in the fuel return line.

3. Disconnect the in-tank fuel pump so it cannot run during the time the vehicle is operating on the external fuel system. If this pump is not disconnected, it may be destroyed.

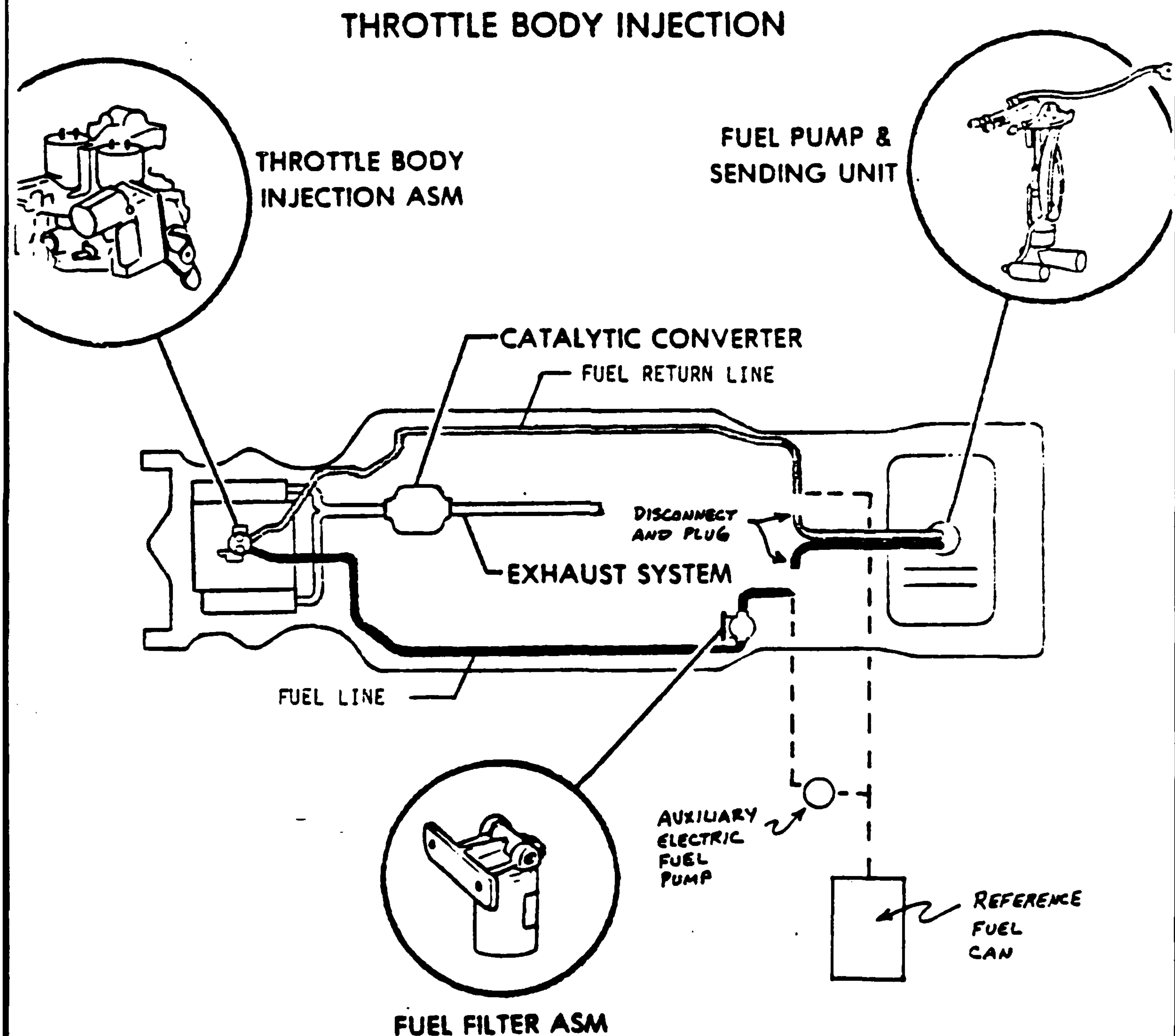
4. When changing from one reference fuel to another, the following steps should be followed:

    a. Disconnect fuel inlet line from reference fuel can and run engine a short time; <u>do not run out of fuel</u> since this will introduce air into the <u>fuel injection system,</u> and excessive cranking will be required to restart the engine.

    b. Insert fuel inlet line in desired reference fuel can; operate vehicle for two miles at a maximum speed of 55 mph during which time four part-throttle accelerations are made. This must be done to ensure that the vehicle fuel system has been purged and contains the desired reference fuel for octane rating.

    c. When changing to another reference fuel, repeat Steps a and b.

PROCEDURE FOR SETTING UP VEHICLES AND HANDLING REFERENCE FUELS
-- VEHICLES EQUIPPED WITH THROTTLE-BODY FUEL INJECTION - (Continued)



PROCEDURE FOR SETTING UP VEHICLES AND HANDLING REFERENCE FUELS -- FORD VEHICLES EQUIPPED WITH CENTRAL FUEL INJECTION SYSTEM

A vehicle schematic of one of Ford's central fuel injection systems is shown on the following drawing (other systems vary in configuration dependent upon engine/model type - see note 1). This fuel system consists of: an electric in-tank fuel pump, primary and secondary full-flow fuel filters, throttle-body assembly with integral fuel pressure regulator and two fuel injectors, fuel supply and return lines. The following procedure is recommended for preparing the vehicle for octane requirement testing:

1. Relieve pressure in fuel system using valve provided on throttle body. Fuel supply lines will remain pressurized for long periods of time after engine shut down. Disconnect and cap the fuel supply and fuel return lines leading from the fuel tank. Access to connection points may be obtained through either the: rear wheel wells, underbody, or engine compartment, dependent upon vehicle type. Install additional lines to the open supply and return lines and lead these lines back into the vehicle.

2. Connect the added fuel supply line to an auxiliary fuel pump. The fuel pressure regulator in the throttle body controls fuel pressure to a nominal 39.9 psi; therefore, it requires an auxiliary fuel pump capable of providing at least 45 psi outlet pressure (see note 1). The added 5.1 psi is needed to sufficiently overcome the pressure head and line restriction losses. Connect a supply line to the auxiliary pump from the reference fuel can. A fuel filter may be required between the auxiliary pump and reference fuel can to protect the pump. Also, connect the added fuel return line to the fuel reference can and vent the reference can to outside the vehicle.

3. Disconnect the electrical supply to the electric in-tank fuel pump, either by disconnecting the plug on the fuel tank or by disarming the inertia switch located in the trunk. Failure to disarm the in-tank fuel pump may result in a damaged pump. The voltage supplied to the inertia switch may be used as an electrical source for the auxiliary fuel pump. This voltage source is controlled by the on-board computer allowing the auxiliary pump to respond the same as would the in-tank fuel pump. When making this connection, do not "splice" into the wire, instead connect the wire lead to the connector.

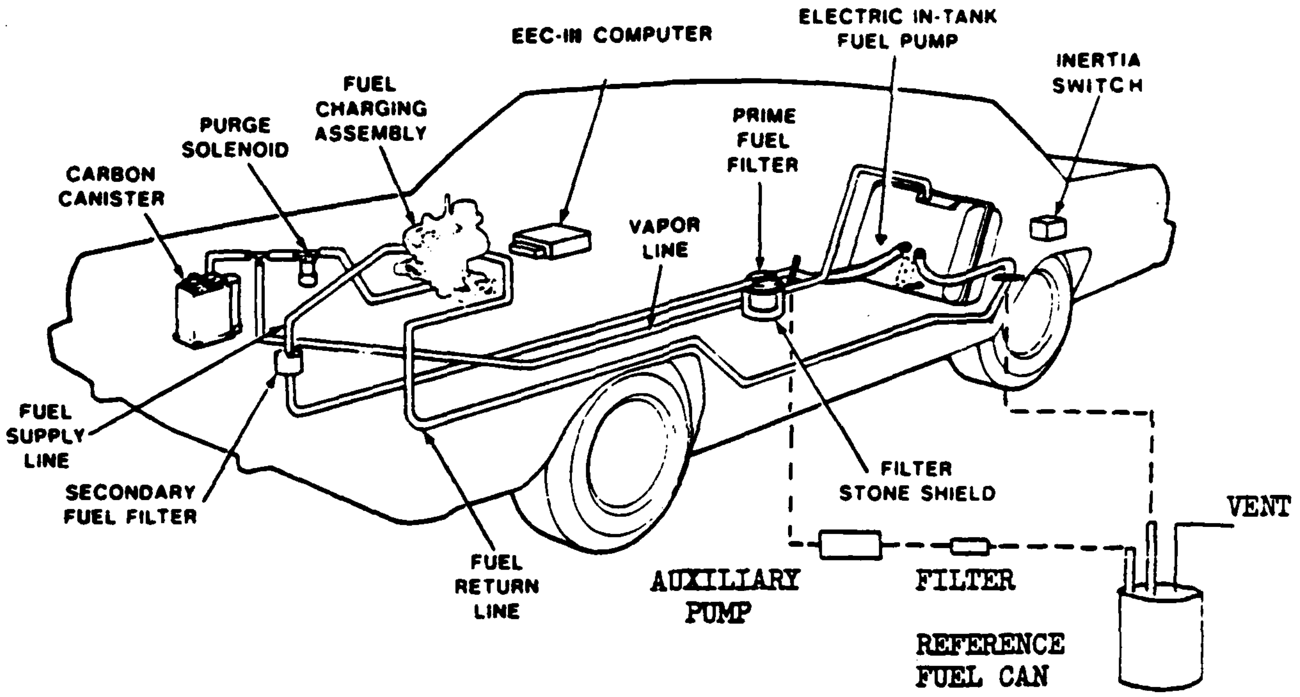
4. When changing from one reference fuel to another, the following steps should be followed, or else reference fuels may become contaminated:

    a. With the engine shut off, disconnect the fuel return line from the reference fuel can and connect it to an extra empty can. Connect the fuel pump supply line to the new reference fuel can and run the engine for approximately 30 seconds, purging the old reference fuel into the extra can (timing is dependent upon length of added fuel lines). After the sytem is purged, shut the engine off and connect the fuel return line to the new reference fuel can forming a closed fuel loop. Now the vehicle is ready to be tested on the desired reference fuel.

    b. When changing to another reference fuel, repeat Step a.

PROCEDURE FOR SETTING UP VEHICLES AND HANDLING REFERENCE FUELS
-- FORD VEHICLES EQUIPPED WITH CENTRAL FUEL INJECTION SYSTEM - (Continued)

CENTRAL FUEL INJECTION
FUEL SYSTEM
(5.0L LINCOLN/MARK VI)



1/ NOTE:

Some vehicles have both a low pressure in-tank fuel pump and a high pressure under body fuel pump. The on-board high pressure pump may be used if supplied with an auxiliary pump. In all cases, it is required that on-board pumps not used, be disarmed. The inertia switch located in the rear of the vehicle will disarm both pumps. Fuel lines on some vehicles may be accessed only in the engine compartment, or by dropping the fuel tank.

SAE RECOMMENDED PRACTICE - SAE J1491 - VEHICLE ACCELERATION MEASUREMENT

3/85

1. <u>PURPOSE</u>

This SAE Recommended Practice provides a standardized means of measuring acceleration performance of passenger cars and light duty trucks.

2. <u>SCOPE</u>

To define significant driving situations involving acceleration, establish meaningful measures of such accelerations, and develop test procedures that will measure a vehicle's maximum performance capabilities during those driving situations.

3. <u>DEFINITION</u>

<u>Unloaded Vehicle Weight</u>: The weight of the vehicle as built to production parts list with maximum capacity of all fluids necessary for operation of the vehicle.

4. <u>INSTRUMENTATION</u> (All instrumentation must be calibrated.)

4.1 <u>Speed-Time</u>: An instrument to measure vehicle speed as a function of elapsed time is used in this procedure. The device must meet the following specifications:

Time:
Accuracy ±0.1 sec.
Resolution 0.1 sec.

Vehicle Speed:
Accuracy ±0.50 mph (0.8 km/h)
Resolution 0.25 mph (0.4 km/h)

Engine Speed (tachometer):
Accuracy ±50 rpm
Resolution 25 rpm

4.2 <u>Temperature</u>: The ambient temperature indicating devices must have a resolution of 2°F or 1°C and an accuracy of ±2°F or ±1°C. The sensing elements must be shielded from radiant heat sources.

4.3 <u>Atmospheric Pressure</u>: A barometer with an accuracy of ±0.2 in Hg or 0.7 kPa.

4.4 Wind: Wind speed and direction during the test should be continuously monitored. Wind measurements should permit the determination of average longitudinal and cross wind components to within ± 1 mph (± 2 km/hr).

4.5 Vehicle Weight: Vehicle weight should be measured to an accuracy of ± 10 lb (± 5 kg) per axle.

4.6 Tire Pressure: Should be measured to an accuracy of ± 1.0 psi (± 7 kPa).

4.7 Distance: A distance indicating device is required. This device must be capable of indicating distance to within 1 ft. and must be capable of accuracy within 5 ft. in 1 mile.

5. *TEST MATERIAL

5.1 Test Vehicle: The test vehicle shall be completely defined on the test vehicle specifications and preparation list. The test vehicle will normally be representative of a standard production built vehicle - any optional or non-standard equipment must be noted/i.e., roof racks, optional mirrors, fog lamps, spoilers, optional axle ratio, etc. Record any equipment that is removed for test.

5.2 Test Fuel: Commercially available fuel as recommended by the manufacturer will normally be used for test purposes. If the information is available or if a special test fuel is used, the fuel specifications should be recorded, such as: fuel generic type, gasoline octane rating or diesel cetane rating, brand name, specific gravity, reid vapor pressure.

5.3 Lubricants: Lubricants used shall conform to the manufacturer's recommendation for the predominant weather condition in which the vehicle is being tested.

6. TEST CONDITIONS

6.1 Ambient Temperature: Test should be conducted at ambient temperatures between 30°F (-1°C) and 90°F (32°C).

6.2 Fog or Rain: Tests may not be run during foggy or rainy conditions.

6.3 Wind Velocity: Tests may not be conducted when wind speeds average more than 15 mph (24 km/h) (or when peak wind speeds are more than 20 mph (32 km/h). The component of the average wind velocity perpendicular to the test road may not exceed an average of 10 mph (16 km/h).

*Reference Attached Vehicle Specification Sheet.

6.4 Road Conditions: Roads must be dry, clean, smooth, and must not exceed 0.5% grade. In addition, the grade should be constant and the road should be straight. The road surface should be concrete or rolled asphalt (or equivalent) and in good condition; testing should not be conducted on slippery roads.

6.5 Speed Limitation: These tests should be run on a controlled track or proving grounds. If run on public roads or highways, speed should not exceed posted speed limit, and vehicle should not interfere with traffic flow or otherwise operate in a manner that would be hazardous.

7. VEHICLE PREPARATION

7.1 Break-In: The vehicle should have at least 2,000 miles of operation before test. Tires must have at least 75% of the tread remaining and tread must be in good condition. All tires must have at least 100 miles of run in before test.

7.2 Vehicle Check List:

7.2.1 The vehicle must be inspected and adjusted where necessary to meet manufacturer's specifications, particularly if vehicle is exhibiting abnormal performance characteristics during acceleration. Tune and time engine, and make all other adjustments, such as front end alignment, and functional checks in accordance with manufacturer's published procedures.

7.2.2 Operate, observe and reset, if necessary, the throttle linkage to ensure wide open throttle occurs.

7.2.3 If vehicle is equipped with automatic transmission, ensure that automatic transmission shift points are within manufacturer's published specifications.

7.2.4 Ensure that brake drag is not excessive.

7.3 Instrumentation: The speed-time measurement device and other necessary test equipment must be installed so that they do not hinder vehicle operation or alter the operating characteristics of the vehicle.

7.4 Test Weight: Unloaded Vehicle Weight +300 lbs. (includes driver and all instrumentation).

7.5 Tire Pressure: The cold tire pressure should be the standard recommended by the manufacturer for the Vehicle Test Weight and installed tires.

7.6 Vehicle Warm-up: The vehicle must be driven a minimum of 20 miles at an average speed of 55 $\pm$5 mph (88 km/h) immediately prior to the test. Alternative schedules that provide equivalent vehicle warm-up can be substituted. There should not be more than a 5-minute time lapse between the warm-up and the start of test.

7.7 Vehicle Data: Record all information as specified on the attached "Vehicle Specification Sheet".

8. TEST PROCEDURE

8.1 Test Schedules: Perform wide open throttle (WOT) accelerations from a standing start and record the following:

0-30 mph	Record Elapsed Time
0-50 mph	Record Elapsed Time
0-60 mph	Record Elapsed Time
1/4 Mile	Record Elapsed Time and Terminal Speed
0-5 sec.	Record Distance Covered and Terminal Speed

Also, perform the following test at wide open throttle:

40-60 mph	Record Elapsed Time

8.2 Automatic Transmission Operating Procedure: From a standing start with engine at idle (braked if necessary), with the shift selector in the "drive" position, accelerate with wide open throttle. The vehicle should be operated to achieve maximum performance with minimum wheel spin. Time zero starts at the instant the driver's foot moves the accelerator pedal.

8.3 Manual Transmission Operating Procedure: From a standing start, the vehicle should be operated to achieve maximum performance with minimum wheel spin. Clutch operation, as well as shift point selection, should be optimized for performance without exceeding the maximum specified engine R.P.M. Time zero starts at the instant of clutch pedal movement.

8.4 40-60 Test Procedure: Starting from a stabilized 40 mph, accelerate with wide open throttle to 60 mph. Manual Transmissions should be run both in top gear and top gear less one, with 4 or 5-speed transmissions. Three speed manual transmission should be run in top gear only. Manual transmissions should not be downshifted during this test.

Automatic transmissions will be allowed to downshift as determined by the vehicle transmission controls.

8.5 Test Data: Run a minimum of 6 individual runs, 3 in each direction. When difficulty is experienced in one run, the pair is excluded.

Record all data specified on the attached "Test Data Sheet".

8.6 Operation of Accessories:

8.6.1 Headlamps are to be off. If the vehicle is equipped with pop-up lamps, the lamp pods should be in the down position. Lights should be on if required for safe vehicle operation, and so noted under remarks on Vehicle Data Sheet.

8.6.2 The heater blower motor shall be used in the "low" position only.

8.6.3 Vehicles equipped with air conditioning should have the compressor clutch wire disconnected before the start of test.

8.6.4 Radio operation is optional.

8.6.5 All other electrical accessories must be in the off position.

8.6.6 Windows should remain closed during test runs.

9. DATA REDUCTION

9.1 Data Calculation: Simple averages will be calculated for all valid multiple test observations (pairs of data).

9.2 Data Presentation: Data should be presented in accordance with the Vehicle Data Sheet. Alternatively, continuous plots may be made of: speed vs. time, time vs. distance, or other data considered appropriate.

9.3 General

9.3.1 Data Variability: Because of unpredictable effects of wind on vehicle performance, the following guideline is suggested as a criterion for test acceptability.

9.3.1.1
The coefficient of variation $\left(\frac{\text{standard deviation of the paired runs}}{\text{mean}}\right.$
of individual runs should not be greater than 3%. On the 40-60 mph acceleration the coefficient of variation should not exceed 6%

Corrections:

9.3.2 Weather ~~Condition~~: No provision for weather correction is made in this procedure. Variables such as temperature, humidity, barometric pressure, wind speed and direction should be considered by the tester in evaluating the test results.

SAE J1082

FUEL ECONOMY MEASUREMENT

ROAD TEST PROCEDURE

FUEL ECONOMY MEASUREMENT—ROAD TEST PROCEDURE—SAE J1082 SEP80

SAE Standard

Report of the Fuel Economy Measurement Procedures Task Force, approved April 1974, last revised by the Passenger Car and Light Truck Fuel Economy Measurement Committee January 1979

1. Purpose—This SAE Standard provides uniform testing procedures for measuring the fuel economy of light duty vehicles (motor vehicles designed primarily for transportation of persons and having a capacity of 12 persons or less, or for transportation of property and rated at 6000 lb (2700 kg) or less) on suitable roads.[1] (The development of the new SAE Motor Vehicle Fuel Economy Measurement Procedures—SAE 75000b.)

2. Scope—This procedure incorporates driving cycles that produce fuel consumption data relating to Urban, Suburban, and Interstate driving patterns. The procedure is intended to be used to determine the relative fuel economy among vehicles and driving patterns under warmed-up conditions on a test track or on suitable roads. The urban driving cycle forms the basis of a Cold-Start Test. Procedure described in SAE Recommended Practice SAE J1256 (May, 1979).

3. Definitions

3.1 Driving Cycles

3.1.1 URBAN CYCLE—Driving pattern defined by section 8.3.4 which is similar to driving conditions in the central business district of a large city.

3.1.2 SUBURBAN CYCLE—Driving pattern defined by section 8.3.5 which is similar to driving conditions in suburban areas of a large city.

3.1.3 INTERSTATE CYCLE—Driving patterns defined by sections 8.3.6 and 8.3.7 which are similar to driving conditions on expressways.

3.2 Test Vehicle—passenger car or light truck prepared for test according to section 7.

3.3 Test Vehicle Weight—unloaded vehicle weight plus 300 lb (136 kg).

3.3.1 UNLOADED VEHICLE WEIGHT—the weight of the vehicle as built to production parts list with maximum capacity of all fluids necessary for operation of the vehicle.

3.3.2 DRIVER AND PASSENGER OR BALLAST WEIGHT—300 lb (136 kg) includes occupants, instrumentation, and ballast, if necessary.

NOTE: This weight will be distributed to properly simulate passenger locations and vehicle attitude (one passenger in driver's position, and one passenger or equivalent weight in front seat passenger position).

3.4 Observed Economy—Observed economy is the fuel economy measured during a driving cycle. It is determined by dividing the actual miles (kilometres) driven on the cycle by the number of gallons (litres) consumed. Economy should be expressed as miles per gallon (kilometres per litre).

3.5 Corrected Economy—Corrected economy is the observed economy multiplied by the correction factors listed in section 10. The corrected fuel economy should be expressed as miles per gallon (kilometres per litre).[2]

3.6 Correction Factors—Factors used to adjust data to the standard ambient condition of 60°F (15.6°C) and 29.00 in Hg (98.2 kPa) and reference fuel properties.

3.7 Test Repeatability Guidelines—These guidelines are intended to provide an estimate of repeatability of test data for replicate tests and are based on a standard deviation equal to 1.9% of the mean.

3.7.1 Estimate of true average (90% confidence interval) fuel economy for vehicle being tested.

$$\text{True average} = \text{observed average} \pm \left[\frac{0.031}{\sqrt{n}} \cdot (\text{observed average})\right]$$

The observed average is the average fuel economy for n tests, where n is the number of replicate tests.

Example 1 (U.S. units)—If a vehicle obtained 14.8 mile/gal and 15.2 mile/gal on two tests on the same cycle, the observed average fuel economy would be 15.0 and the true average (90% confidence) would be

$$15.0 \pm \left[\frac{0.031}{\sqrt{2}} \cdot 15.0\right] = 15.0 \pm 0.3 \text{ mile/gal}$$

Example 2 (SI units)—If a vehicle obtained 6.29 km/L and 6.46 km/L on two tests on the same cycle, the observed average fuel economy would

[1] This procedure does not apply to mandatory fuel economy standards for passenger vehicles first established by the "Energy Policy and Conservation Act," Public Law 94-163, 94th Congress S. 622, December 22, 1975. Details of the mandatory dynamometer procedure can be obtained by contacting Environmental Protection Agency, Fourth and M Streets, S.W., Washington, DC 20460.

[2] The corrected fuel economy may be expressed in terms of fuel consumption L/100 km.

6.38 km/L and the true average (90% confidence) would be:

$$6.38 \pm \left[\frac{0.031}{\sqrt{2}} \cdot 6.38\right] = 6.38 \pm 0.14 \text{ km/L}$$

3.7.2 ESTIMATE OF THE 95TH PERCENTILE RANGE FOR REPLICATE TESTS—The 95th percentile range = R = 0.019Q·(observed average) where Q = the critical value obtained from a table for the Studentized[3] range and the observed average represents the average for n tests.

Selected values for 0.019Q are:

n	0.019Q
2	0.053
3	0.063
4	0.069
5	0.073
10	0.085

Example 1 (U.S. units)—If a vehicle obtains 14.5 mile/gal and 15.5 mile/gal on two tests on the same cycle, the observed average fuel economy would be 15.0 mile/gal and the 95th percentile range would be:

$$R = 0.053 \cdot 15.0 = 0.8 \text{ mile/gal}$$

The difference between the two tests is 1.0 mile/gal which is greater than the difference that would be expected for 95% of the cases in which two tests were conducted. Consequently, additional tests should be conducted to provide more confidence in the average fuel economy.

Example 2 (SI units)—If a vehicle obtains 6.20 km/L and 6.60 km/L on two tests on the same cycle, the observed average fuel economy would be 6.40 km/L and the 95th percentile range would be:

$$R = 0.053 \cdot 6.40 = 0.34 \text{ km/L}$$

The difference between the two tests is 0.4 km/L which is greater than the difference that would be expected for 95% of the cases in which two tests were conducted. Consequently, additional tests should be conducted to provide more confidence in the average fuel economy.

4. *Instrumentation*—All instrumentation shall be calibrated.

4.1 **Fuel**—The fuel measurement device must be compatible with the vehicle fuel system and should alter the fuel temperature and pressure as little as practical. The fuel measurement system must be accurate to within 0.5% of the fuel used during a driving cycle.

4.2 **Speed**—The speed indicating device shall indicate vehicle speed in miles per hour (kilometres per hour) and be accurate within 0.5 mile/h (1 km/h).

4.3 **Acceleration**—The acceleration indicating device must be capable of indicating both positive and negative acceleration. It shall indicate acceleration/deceleration in ft/s² (m/s²) and be accurate within 0.5 ft/s² (0.2 m/s²).

4.4 **Time**—The time measuring instrument must be capable of measuring time interval to 0.1 s and be accurate within 0.1 s in 1 min.

4.5 **Temperature**—The temperature indicating devices must be capable of measuring to the nearest 2°F or 1°C. Accuracy must be within ±2°F or ±1°C. The sensing element shall be shielded from radiant heat sources.

4.6 **Atmospheric Pressure**—An aneroid or mercury barometer should be used. This device should be accurate within 0.1 in Hg or 0.3 kPa.

4.7 **Wind**—Wind speed should be measured with a device that provides an indication of wind speed that is accurate within 2 mile/h (3 km/h). Wind direction should also be indicated.

4.8 **Distance**—A distance indicating device is required if the tests are not conducted on a premarked course. This device must be capable of indicating distance to within 15 ft (5 m) and must be capable of accuracy within 30 ft in 1 mile (6 m in 1 km).

4.9 **Vehicle Weight**—Vehicle weight should be measured with a device that is accurate within ±0.5% with minimum resolution of 20 lb (10 kg).

5. *Test Material*

5.1 **Test Vehicle**—The test vehicle shall be completely defined on the Test Vehicle Specifications and Preparation List. (The test vehicle will normally be representative of a production built vehicle—any exceptions must be properly noted.)

5.2 **Test Fuel**—Normally, service station fuel will be satisfactory for test purposes. Distillation, specific gravity, and Reid Vapor Pressure should be recorded.

5.3 **Lubricants**—Lubricants used shall conform to the manufacturer's recommendation for the predominant weather condition in which the vehicle is being tested.

6. *Test Conditions*

6.1 **Ambient Temperature**—Tests should be conducted at ambient temperatures between 30°F (−1°C) and 90°F (32°C).

6.2 **Wind Velocity**—Tests must not be conducted when average wind speed exceeds 15 mile/h (24 km/h) or when gusts exceed 20 mile/h (32 km/h).

6.3 **Road Conditions**—Roads must be dry, clean, smooth, and not exceed 1.0% grade. If operating on a closed track, the start and stop points should be selected such that the schedule elevation difference is 10 ft (3 m) or less.

6.4 It is recommended that roadside markers be used to indicate the points at which speed changes are to be made as indicated in section 8.3.

7. *Test Vehicle Preparation*

7.1 **Break-In**—The vehicle should have accumulated a minimum of 2000 mile (3200 km) of operation prior to test. At least 1000 mile (1600 km) must have been driven at cycling speeds between 40 mile/h (64 km/h) and maximum legal highway speeds. If a closed track is available for break-in, the maximum speed should not exceed 100 mile/h (160 km/h). Chassis dynamometer break-in is acceptable. All of the tires must have operated at least 100 road or track miles (160 km) prior to the test. Tires must have at least 75% of the tread remaining and tread must be in good condition.

7.2 **Inspection**—The vehicle must be inspected and adjusted where necessary to meet manufacturer's specifications. Checks are specified on the Test Vehicle Specifications and Preparation List.

7.3 **Instrumentation**—The fuel measuring device and other instrumentation, as necessary, must be installed in a manner not to hinder the vehicle operation or operating characteristics.

7.4 **Test Weight**—The vehicle weight must be adjusted to provide the test weight indicated in section 3.3 (this test weight includes instrumentation and operator).

7.5 **Tire Pressure**—The cold tire pressure should be the minimum recommended by the manufacturer for the vehicle test weight.

8. *Test Procedure*

8.1 **Warm-Up**—The vehicle must be driven a minimum of 20 miles (32 km) at approximately 55 mile/h (90 km/h) or a maximum legal highway speed to stabilize engine and drivetrain operating temperatures immediately before running the first driving cycle.

8.2 **Vehicle Controls**

8.2.1 Air conditioning compressor, headlamps, and other accessories that consume power should be turned off unless required for safe vehicle operation.

8.2.2 Vehicle windows must remain closed while fuel consumption is being measured during the Suburban and Interstate Cycles.

8.3 **Driving Schedules**

8.3.1 GENERAL DRIVING INSTRUCTIONS

8.3.1.1 Vehicles incapable of attaining acceleration rates specified by the driving schedules will be driven at maximum acceleration until the specified schedule speed is reached.

8.3.1.2 Vehicles with automatic transmissions should be driven with the transmission in drive range. If transmission hunting should be encountered at a specified acceleration, the acceleration should be increased to maintain the transmission in the lower gear and this departure from the schedule noted on the data form.

8.3.1.3 Vehicles equipped with manual transmissions will be operated in the following manner: Idles will be made in gear, clutch disengaged. Decelerations will be made in gear, and the clutch will be disengaged at 15 mile/h (24 km/h) on a stop. All cruise operation should be in the highest gear that will prevent engine lugging. Downshifts will be permitted to obtain specified acceleration rate after a deceleration or to obtain smooth engine operation at a slow speed. The following manual transmission shift speeds may be modified as necessary to avoid engine lugging or overspeed. Departure from specified shift speeds should be noted on the data form.

8.3.1.4 Vehicles with manual 3-speed transmissions will be shifted (1-2) at 15 mile/h (24 km/h) and (2-3) at 25 mile/h (40 km/h) or when a lower specified cruise speed is reached. For example, the 20 mile/h (32 km/h) cruise after accelerating at the 0.5, 0.7, and 0.8 mile (0.80, 1.13, and 1.29 km) markers in the Urban Cycle would be conducted in the highest gear that will prevent engine lugging.

8.3.1.5 Vehicles with manual 4-speed transmissions, except truck-type transmissions will be shifted (1-2) at 15 mile/h (24 km/h), (2-3) at 25 mile/h (40 km/h), and (3-4) at 35 mile/h (56 km/h), or when a lower specified cruise speed is reached.

8.3.1.6 Vehicles with manual truck-type transmissions containing a creeper gear will not use the creeper gear during the driving cycles.

8.3.1.7 Vehicles with manual 5-speed transmissions or manually engaged overdrive will be shifted (1-2) at 15 mile/h (24 km/h), (2-3) at 25 mile/h (40 km/h), (3-4) at 40 mile/h (64 km/h) during accelerations. Upshift to 5th gear at the manufacturer's recommended speed for smooth operation at cruising speed.

8.3.1.8 Vehicles with overdrive transmissions where the overdrive unit engages automatically are to be driven with the actuator switch in a position which ensures engagement when conditions for operation are reached. On vehicles where overdrive is engaged manually (such as a designated overdrive gear), upshift to overdrive at the manufacturer's recommended speed for

[3] D. B. Owen, "Handbook of Statistical Tables," Reading, MA: Addison-Wesley Publishing Co., Inc., 1962, pp. 144-148.

smooth operation. Where specified accelerations cannot be maintained in overdrive, make the complete acceleration in the conventional gear and engage overdrive upon reaching the specified speed. Drive complete Urban route with the overdrive locked out.

8.3.1.9 On vehicles with automatic transmission, brakes should be applied to maintain the schedule speed if the engine idle results in vehicle speed above that specified. For manual transmission vehicles, the transmission should be down-shifted.

8.3.2 General Cycle Instructions

8.3.2.1 The Urban Cycle will normally be run on a 2 mile (3.2 km) straightaway. The Suburban and Interstate Cycles may be run on either a closed track or a straightaway. For tests on a straightaway less than 2 mile (3.2 km) long, turn-arounds may be made at normal stop intervals. A test on a straightaway shall consist of successive cycles run in opposite directions to minimize wind and grade effects. A test on a closed track shall consist of one cycle.

8.3.2.2 Effort should be made to perform the Interstate Schedule acceleration and decelerations as specified. The Urban and Suburban acceleration and decelerations should be maintained within ±1 ft/s^2 (0.3 m/s^2) of that specified. Vehicle speeds should be maintained within ±1 mile/h (1.6 km/h).

8.3.2.3 Driving cycle maneuvers are initiated at the points indicated, except for the stop at the end of the Urban Cycle, which is to be completed by the point indicated.

8.3.2.4 Fuel temperature will be recorded on the data form during all idle periods or at the beginning and end of the cycle on the Interstate Schedules.

8.3.2.5 Record weather data for each test cycle.

8.3.2.6 Ambient conditions should be such that repeatability may be attained in as few cycles as possible.

◆ 8.3.2.7 Fuel consumed for each schedule, as indicated by a fuel meter, should be the average of at least two consecutive tests that repeat within 2%. If the measured fuel readings are not within 2%, additional tests are required until this criteria is met before calculating the fuel economy. Elapsed time should repeat within 1%.

8.3.2.8 The driving cycles are to be conducted on warmed-up vehicles (refer to initial warm-up procedure in section 8.1).

8.3.3 General Cycle Summary Table:

Cycle	Average Speed mile/h	(km/h)	Nominal Test Time s	Test Distance mile	(km)	Idle Time s	Stops
Urban	15.6	(25.1)	463	2.0	(3.22)	60	8
Suburban	41.1	(66.1)	455	5.2	(8.37)	14	2
55 mile/h Interstate	55.0	(88.5)	308	4.7	(7.56)	—	—
70 mile/h Interstate	70.0	(112.6)	242	4.7	(7.56)	—	—

8.3.4 Urban Driving Cycle:

Distance mile	(km)	Operation
0.0	(0.0)	Start fuel meter and timing device, idle 15 s, accelerate to 15 mile/h (24 km/h) at 7 ft/s^2 (2.1 m/s^2). Proceed at 15 mile/h (24 km/h) to the 0.2 mile (0.32 km) marker.
0.2	(0.32)	Stop at 4 ft/s^2 (1.2 m/s^2), accelerate to 15 mile/h (24 km/h) at 7 ft/s^2 (2.1 m/s^2). Proceed at 15 mile/h (24 km/h) to the 0.3 mile (0.48 km) marker.
0.3	(0.48)	Decelerate to 5 mile/h (8 km/h) at 4 ft/s^2 (1.2 m/s^2), accelerate to 15 mile/h (24 km/h) at 7 ft/s^2 (2.1 m/s^2). Proceed at 15 mile/h (24 km/h) to the 0.5 mile (0.80 km) marker.
0.5	(0.80)	Stop at 4 ft/s^2 (1.2 m/s^2), record fuel temperature and idle 15 s, accelerate to 20 mile/h (32 km/h) at 7 ft/s^2 (2.1 m/s^2). Proceed at 20 mile/h (32 km/h) to the 0.7 mile (1.13 km) marker.
0.7	(1.13)	Stop at 4 ft/s^2 (1.2 m/s^2), accelerate to 20 mile/h (32 km/h) at 7 ft/s^2 (2.1 m/s^2). Proceed at 20 mile/h (32 km/h) to the 0.8 mile (1.29 km) marker.
0.8	(1.29)	Decelerate to 10 mile/h (16 km/h) at 4 ft/s^2 (1.2 m/s^2), accelerate to 20 mile/h (32 km/h) at 5 ft/s^2 (1.5 m/s^2). Proceed at 20 mile/h (32 km/h) to the 1.0 mile (1.61 km) marker.
1.0	(1.61)	Stop at 4 ft/s^2 (1.2 m/s^2), record fuel temperature and idle 15 s, accelerate to 15 mile/h (24 km/h) at 7 ft/s^2 (2.1 m/s^2), then to 25 mile/h (40 km/h) at 5 ft/s^2 (1.5 m/s^2). Proceed at 25 mile/h (40 km/h) to the 1.2 mile (1.93 km) marker.
1.2	(1.93)	Stop at 4 ft/s^2 (1.2 m/s^2), accelerate to 15 mile/h (24 km/h) at 7 ft/s^2 (2.1 m/s^2), then to 25 mile/h (40 km/h) at 5 ft/s^2 (1.5 m/s^2). Proceed at 25 mile/h (40 km/h) to the 1.3 mile (2.09 km) marker.
1.3	(2.09)	Decelerate to 15 mile/h (24 km/h) at 4 ft/s^2 (1.2 m/s^2), accelerate to 25 mile/h (40 km/h) at 5 ft/s^2 (1.5 m/s^2). Proceed at 25 mile/h (40 km/h) to the 1.5 mile (2.41 km) marker.
1.5	(2.41)	Stop at 4 ft/s^2 (1.2 m/s^2), record fuel temperature and idle 15 s, accelerate to 15 mile/h (24 km/h) at 7 ft/s^2 (2.1 m/s^2), then to 30 mile/h (48 km/h) at 5 ft/s^2 (1.5 m/s^2). Proceed at 30 mile/h (48 km/h) to the 1.7 mile (2.74 km) marker.
1.7	(2.74)	Stop at 4 ft/s^2 (1.2 m/s^2), accelerate to 15 mile/h (24 km/h) at 7 ft/s^2 (2.1 m/s^2) and then to 30 mile/h (48 km/h) at 5 ft/s^2 (1.5 m/s^2). Proceed at 30 mile/h (48 km/h) to the 1.8 mile (2.90 km) marker.
1.8	(2.90)	Decelerate to 20 mile/h (km/h) at 4 ft/s^2 (1.2 m/s^2), accelerate to 30 mile/h (48 km/h) at 5 ft/s^2 (1.5 m/s^2). Proceed at 30 mile/h (48 km/h).
2.0	(3.22)	Begin braking at 4 ft/s^2 (1.2 m/s^2) to arrive at stop at 2.0 mile (3.22 km) marker. Stop fuel meter and timing device at stop, record fuel consumed, elapsed time, and fuel temperature.
0.0	(0.0)	Run Recheck cycle.

8.3.5 Suburban Driving Cycle:

Distance mile	(km)	Operation
0.0	(0.0)	Approach starting line at 40 mile/h (64 km/h). At line, start fuel measuring and timing devices, accelerate to 60 mile/h (97 km/h) at 3 ft/s^2 (0.9 m/s^2). Proceed at 60 mile/h (97 km/h) to the 0.7 mile (1.13 km) marker.
0.7	(1.13)	Decelerate to 30 mile/h (48 km/h) at 4 ft/s^2 (1.2 m/s^2). Accelerate to 50 mile/h (80 km/h) at 3 ft/s^2 (0.9 m/s^2). Proceed at 50 mile/h (80 km/h) to the 2.0 mile (3.22 km) marker.
2.00	(3.22)	Stop at 4 ft/s^2 (1.2 m/s^2), record fuel temperature and idle 7 s, accelerate to 15 mile/h (24 km/h) at 7 ft/s^2 (2.1 m/s^2). Continue accelerating to 25 mile/h (40 km/h) at 5 ft/s^2 (1.5 m/s^2). Continue accelerating to 40 mile/h (64 km/h) at 3 ft/s^2 (0.9 m/s^2). Proceed at 40 mile/h (64 km/h) to the 2.6 mile (4.18 km) marker.
2.60	(4.18)	Accelerate to 50 mile/h (80 km/h) at 3 ft/s^2 (0.9 m/s^2). Proceed at 50 mile/h (80 km/h) to the 3.3 mile (5.31 km) marker.
3.30	(5.31)	Stop at 4 ft/s^2 (1.2 m/s^2), record fuel temperature and idle 7 s, accelerate to 15 mile/h (24 km/h) at 7 ft/s^2 (2.1 m/s^2). Continue accelerating to 25 mile/h (40 km/h) at 5 ft/s^2 (1.5 m/s^2). Continue accelerating to 40 mile/h (64 km/h) at 3 ft/s^2 (0.9 m/s^2). Proceed at 40 mile/h (64 km/h) to the 5.2 mile (8.37 km) marker.
5.2	(8.37)	Stop fuel measuring and timing devices while driving at 40 mile/h (64 km/h) at 5.2 mile (8.37 km). Record fuel consumed, elapsed time, and fuel temperature.
0.0	(0.0)	Run recheck cycle.

8.3.6 Interstate Cycle 55 mile/h (89 km/h)

Distance mile	(km)	Operation
0.0	(0.0)	Approach the starting line at 55 mile/h (89 km/h). Record fuel temperature at line, start fuel measuring and timing devices. Proceed at 55 mile/h (89 km/h) to the 0.2 mile (0.32 km) marker.
0.20	(0.32)	Accelerate to 60 mile/h (97 km/h) at ft/s^2 (0.3 m/s^2). Immediately decelerate to 50 mile/h (80 km/h) at 1 ft/s^2 (0.3 m/s^2). Immediately accelerate

to 55 mile/h (89 km/h) at 1 ft/s² (0.3 m/s²). Proceed at 55 mile/h (89 km/h) to the 1.2 mile (1.93 km) marker.

1.2	(1.93)	Repeat accelerations and deceleration as at 0.20 mile (0.32 km). Proceed to the 2.2 mile (3.54 km) marker.
2.2	(3.54)	Repeat accelerations and decelerations as at 0.20 mile (0.32 km). Proceed to the 3.2 mile (5.15 km) marker.
3.2	(5.15)	Repeat accelerations and decelerations as at 0.20 mile (0.32 km). Proceed to the 4.7 mile (7.56 km) marker
4.7	(7.56)	Stop fuel measuring and timing device while driving at 55 mile/h (89 km/h) at 4.7 mile (7.56 km). Record fuel consumed, elapsed time, and fuel temperature.
0.0	(0.0)	Run recheck cycle.

8.3.7 Interstate Cycle 70 mile/h (113 km/h):

Distance mile	(km)	Operation
0.0	(0.0)	Approach the starting line at 70 mile/h (113 km/h). Record fuel temperature at line, start fuel measuring and timing devices. Proceed at 70 mile/h (113 km/h) to the 0.2 mile (0.32 km) marker.
0.20	(0.32)	Accelerate to 75 mile/h (121 km/h) at 1 ft/s² (0.3 m/s²). Immediately decelerate to 65 mile/h (105 km/h) at 1 ft/s² (0.3 m/s²). Immediately accelerate to 70 mile/h (113 km/h) at 1 ft/s² (0.3 m/s²). Proceed at 70 mile/h (113 km/h) to the 1.2 mile (1.93 km) marker.
1.2	(1.93)	Repeat accelerations and decelerations as at 0.20 mile (0.32 km). Proceed to the 2.2 mile (3.54 km) marker.
2.2	(3.54)	Repeat accelerations and decelerations as at 0.20 mile (0.32 km). Proceed to the 3.2 mile (5.15 km) marker.
3.2	(5.15)	Repeat accelerations and decelerations as at 0.20 mile (0.32 km). Proceed to the 4.7 mile (7.56 km) marker.
4.7	(7.56)	Stop fuel measuring and timing device while driving at 70 mile/h (113 km/h) at 4.7 mile (7.56 km). Record fuel consumed, elapsed time, and fuel temperature.
0.0	(0.0)	Run recheck cycle.

9. Data Recording—Data shall be entered as required on test data forms.

9.1 Test Vehicle Specifications and Preparation List

9.2 Data Form

9.3 Summary Sheet

10. Data Correction (U. S. Units)

10.1 Reference Conditions

Ambient Temperature	60°F
Fuel Temperature	60°F
Barometric Pressure	29.00 in Hg
Fuel Gravity (Gasoline)	0.737 Specific Gravity, 60.5° API Gravity
Fuel Gravity (ASTM 1D)	0.820 Specific Gravity, 41.0° API Gravity
(ASTM 2D)	0.845 Specific Gravity, 36.0° API Gravity
Fuel Net Heating Value	
(ASTM 1D)	126 700 Btu/gal
(ASTM 2D)	129 900 Btu/gal

10.2 Fuel Economy Correction (Gasoline)

10.2.1 Definitions (units)

T_A —Average ambient temperature during test cycle (°F)

T_f —Average fuel temperature at measuring instrument during test cycle (°F)

P —Average barometric pressure during test cycle (in Hg)

G_s —Specific gravity of test fuel at 60°F

G_A —API gravity of test fuel at 60°F

FE_o—Observed fuel economy (mile/gal)

FE_c—Corrected fuel economy (mile/gal)

10.2.2 Correction Formula

$$FE_c = FE_o \cdot C_1 \cdot C_2 \cdot C_3 \cdot C_4$$

10.2.3 Correction Factors

$C_1 = 1 + 0.0014\,(60 - T_A)$

$C_2 = 1.0$ Urban Cycle

$= 1.0 + 0.0072\,(P - 29.00)$ Suburban Cycle

$= 1.0 + 0.0084\,(P - 29.00)$ 55 mile/h Interstate Cycle

$= 1.0 + 0.0144\,(P - 29.00)$ 70 mile/h Interstate Cycle

$C_3 = 1.0 + 0.8\,(0.737 - G_s)$

or

$C_3 = 1.0 + 0.0032\,(G_A - 60.5)$

C_4 is derived from Table 1 based on gravity of fuel at 60°F and T_f or from the following analytical equation.

$$C_4 = a + bT_f + cT_f^2$$

where the coefficients a, b, c are

ASTM Fuel Group

Coefficient	2	3	4
a	9.7108 (10)⁻¹	9.6513 (10)⁻¹	9.5982 (10)⁻¹
b	4.6590 (10)⁻⁴	5.5473 (10)⁻⁴	6.3156 (10)⁻⁴
c	2.6156 (10)⁻⁷	4.3541 (10)⁻⁷	6.2624 (10)⁻⁷

10.3 Fuel Economy Correction (Diesel)

Note—The method for correcting observed fuel economy for vehicles with diesel engines has not been investigated to the same degree that it has for gasoline powered vehicles. However, the ambient temperature and barometric pressure corrections are primarily for changes in air density and its effect on aerodynamic drag. Hence, the correction factors for gasoline powered vehicles are recommended for use until additional data become available.

10.3.1 Definitions (see section 10.2.1)

H = Volumetric heating value of diesel test fuel (Btu/gal)

10.3.2 Correction Formula

$$FE_c = FE_o \cdot C_1 \cdot C_2 \cdot C_3 \cdot C_4$$

10.3.3 Correction Factors

$C_1 = 1.0 + 0.0014\,(60 - T_A)$

$C_2 = 1.0$ Urban Cycle

$= 1.0 + 0.0072\,(P - 29.00)$ Suburban Cycle

$= 1.0 + 0.0084\,(P - 29.00)$ 55 mile/h Interstate Cycle

$= 1.0 + 0.0144\,(P - 29.00)$ 70 mile/h Interstate Cycle

$C_3 = K/H$

$K = 126\,700$ (ASTM 1D type fuels)

$= 129\,900$ (ASTM 2D type fuels)

H—shall be obtained from Fig. 1 by using the observed API gravity at 60°F and the 50% distillation point or from calorimeter tests

C_4 is derived from Table 1 based on gravity of fuel at 60°F and T_f or from the following analytical equation:

$$C_4 = a + bT_f + cT_f^2$$

where the coefficients a, b, c are:

ASTM Fuel Group

Coefficient	1	2
a	9.7645 (10)⁻¹	9.7108 (10)⁻¹
b	3.8674 (10)⁻⁴	4.6590 (10)⁻⁴
c	9.3735 (10)⁻⁸	2.6156 (10)⁻⁷

11. Data Correction (SI Units)

11.1 Reference Conditions

Ambient temperature	15.6°C
Fuel temperature	15.6°C
Barometric pressure	98 kPa
Fuel gravity (gasoline)	0.737 specific gravity
Fuel gravity (ASTM 1D)	0.820 specific gravity
(ASTM 2D)	0.845 specific gravity
Fuel Net Heating Value	
(ASTM 1D)	35.31 MJ/L
(ASTM 2D)	36.21 MJ/L

11.2 Fuel Economy Correction (Gasoline)

11.2.1 Definitions (Units)

T_A —Average ambient temperature during test cycle (°C)

T_f —Average fuel temperature during test cycle (°C)

P —Average barometric pressure during test cycle (kPa)

G_s —Specific gravity of test fuel at 15.6°C

FE_o—Observed fuel economy (km/L)

FE_c—Corrected fuel economy (km/L)

D-40

ATTACHMENT 5

TABLE 1—C_t—FUEL TEMPERATURE CORRECTION FACTOR* (U. S. UNITS)

ASTM Group Number	Specific Gravity Range	API Gravity Range, °API
1	0.8499–0.9659	15.0–34.9
2	0.7754–0.8498	35.0–50.9
3	0.7239–0.7753	51.0–63.9
4	0.6723–0.7238	64.0–78.9

Fuel Temp., °F	C_t Group 1	C_t Group 2	C_t Group 3	C_t Group 4	Fuel Temp., °F	C_t Group 1	C_t Group 2	C_t Group 3	C_t Group 4
0	0.9765	0.9711	0.9651	0.9598	76	1.0064	1.0081	1.0098	1.0114
1	0.9768	0.9715	0.9656	0.9604	77	1.0068	1.0085	1.0104	1.0121
2	0.9772	0.9720	0.9662	0.9611	78	1.0071	1.0090	1.0110	1.0129
3	0.9776	0.9725	0.9667	0.9616	79	1.0076	1.0095	1.0116	1.0136
4	0.9780	0.9730	0.9673	0.9623	80	1.0080	1.0100	1.0122	1.0143
5	0.9784	0.9734	0.9679	0.9629	81	1.0084	1.0105	1.0129	1.0151
6	0.9788	0.9739	0.9684	0.9636	82	1.0088	1.0110	1.0136	1.0158
7	0.9791	0.9743	0.9690	0.9642	83	1.0092	1.0115	1.0142	1.0166
8	0.9795	0.9748	0.9696	0.9649	84	1.0096	1.0120	1.0148	1.0173
9	0.9799	0.9753	0.9701	0.9655	85	1.0100	1.0126	1.0154	1.0180
10	0.9803	0.9758	0.9707	0.9661	86	1.0104	1.0131	1.0160	1.0187
11	0.9807	0.9763	0.9713	0.9668	87	1.0108	1.0136	1.0167	1.0195
12	0.9811	0.9768	0.9718	0.9675	88	1.0112	1.0141	1.0173	1.0202
13	0.9814	0.9772	0.9724	0.9681	89	1.0116	1.0146	1.0179	1.0209
14	0.9818	0.9777	0.9730	0.9688	90	1.0120	1.0151	1.0185	1.0218
15	0.9822	0.9782	0.9735	0.9695	91	1.0124	1.0156	1.0192	1.0225
16	0.9826	0.9787	0.9741	0.9701	92	1.0129	1.0162	1.0198	1.0232
17	0.9830	0.9790	0.9747	0.9708	93	1.0133	1.0167	1.0205	1.0240
18	0.9835	0.9795	0.9753	0.9714	94	1.0137	1.0172	1.0211	1.0247
19	0.9839	0.9800	0.9759	0.9721	95	1.0141	1.0177	1.0218	1.0254
20	0.9843	0.9805	0.9765	0.9728	96	1.0145	1.0182	1.0224	1.0262
21	0.9846	0.9810	0.9770	0.9734	97	1.0148	1.0187	1.0230	1.0269
22	0.9850	0.9814	0.9776	0.9741	98	1.0152	1.0193	1.0236	1.0276
23	0.9854	0.9819	0.9782	0.9748	99	1.0156	1.0198	1.0243	1.0285
24	0.9858	0.9824	0.9788	0.9753	100	1.0160	1.0203	1.0249	1.0292
25	0.9862	0.9829	0.9793	0.9760	101	1.0165	1.0208	1.0255	1.0300
26	0.9866	0.9834	0.9799	0.9767	102	1.0169	1.0213	1.0262	1.0307
27	0.9870	0.9839	0.9805	0.9773	103	1.0173	1.0219	1.0269	1.0314
28	0.9874	0.9843	0.9811	0.9780	104	1.0177	1.0224	1.0275	1.0322
29	0.9878	0.9848	0.9816	0.9787	105	1.0181	1.0229	1.0282	1.0330
30	0.9881	0.9853	0.9822	0.9793	106	1.0185	1.0234	1.0288	1.0338
31	0.9885	0.9858	0.9828	0.9800	107	1.0190	1.0240	1.0294	1.0346
32	0.9889	0.9863	0.9834	0.9807	108	1.0194	1.0245	1.0301	1.0353
33	0.9893	0.9868	0.9840	0.9814	109	1.0198	1.0250	1.0307	1.0360
34	0.9897	0.9873	0.9845	0.9820	110	1.0201	1.0255	1.0314	1.0368
35	0.9901	0.9878	0.9851	0.9827	111	1.0205	1.0261	1.0320	1.0376
36	0.9905	0.9882	0.9857	0.9834	112	1.0209	1.0266	1.0327	1.0384
37	0.9909	0.9887	0.9863	0.9841	113	1.0213	1.0271	1.0334	1.0392
38	0.9913	0.9892	0.9869	0.9847	114	1.0218	1.0276	1.0340	1.0399
39	0.9917	0.9897	0.9875	0.9854	115	1.0222	1.0282	1.0347	1.0407
40	0.9921	0.9902	0.9880	0.9861	116	1.0226	1.0287	1.0353	1.0414
41	0.9925	0.9907	0.9886	0.9868	117	1.0230	1.0291	1.0359	1.0422
42	0.9928	0.9912	0.9892	0.9875	118	1.0234	1.0296	1.0366	1.0431
43	0.9932	0.9917	0.9898	0.9881	119	1.0238	1.0302	1.0372	1.0438
44	0.9936	0.9922	0.9904	0.9888	120	1.0243	1.0307	1.0380	1.0446
45	0.9940	0.9926	0.9910	0.9895	121	1.0246	1.0312	1.0386	1.0454
46	0.9944	0.9930	0.9916	0.9902	122	1.0250	1.0318	1.0393	1.0461
47	0.9948	0.9935	0.9922	0.9910	123	1.0254	1.0323	1.0399	1.0469
48	0.9952	0.9940	0.9928	0.9917	124	1.0258	1.0328	1.0406	1.0478
49	0.9956	0.9945	0.9933	0.9924	125	1.0263	1.0334	1.0412	1.0485
50	0.9960	0.9950	0.9939	0.9930	126	1.0267	1.0339	1.0419	1.0493
51	0.9964	0.9955	0.9946	0.9937	127	1.0271	1.0344	1.0425	1.0501
52	0.9968	0.9960	0.9952	0.9944	128	1.0275	1.0350	1.0433	1.0509
53	0.9973	0.9965	0.9958	0.9951	129	1.0279	1.0355	1.0440	1.0517
54	0.9977	0.9971	0.9964	0.9958	130	1.0283	1.0360	1.0446	1.0525
55	0.9981	0.9976	0.9971	0.9965	131	1.0287	1.0366	1.0452	1.0533
56	0.9984	0.9980	0.9977	0.9973	132	1.0291	1.0371	1.0459	1.0541
57	0.9988	0.9985	0.9983	0.9980	133	1.0295	1.0377	1.0466	1.0548
58	0.9992	0.9990	0.9988	0.9986	134	1.0300	1.0382	1.0473	1.0557
59	0.9996	0.9995	0.9994	0.9993	135	1.0304	1.0387	1.0480	1.0565
60	1.0000	1.0000	1.0000	1.0000	136	1.0308	1.0393	1.0486	1.0573
61	1.0004	1.0005	1.0006	1.0007	137	1.0312	1.0398	1.0493	1.0581
62	1.0008	1.0010	1.0012	1.0014	138	1.0316	1.0404	1.0500	1.0589
63	1.0012	1.0015	1.0018	1.0021	139	1.0320	1.0409	1.0506	1.0598
64	1.0016	1.0020	1.0074	1.0028	140	1.0324	1.0414	1.0513	1.0606
65	1.0020	1.0025	1.0030	1.0035	141	1.0328	1.0420	1.0520	1.0613
66	1.0024	1.0030	1.0036	1.0042	142	1.0333	1.0425	1.0527	1.0621
67	1.0028	1.0035	1.0042	1.0049	143	1.0337	1.0431	1.0534	1.0630
68	1.0032	1.0040	1.0049	1.0056	144	1.0341	1.0436	1.0541	1.0638
69	1.0036	1.0045	1.0055	1.0064	145	1.0345	1.0442	1.0547	1.0646
70	1.0040	1.0050	1.0061	1.0072	146	1.0350	1.0447	1.0554	1.0654
71	1.0044	1.0055	1.0067	1.0079	147	1.0353	1.0452	1.0561	1.0662
72	1.0048	1.0060	1.0074	1.0086	148	1.0357	1.0458	1.0568	1.0671
73	1.0052	1.0065	1.0080	1.0093	149	1.0362	1.0464	1.0575	1.0679
74	1.0056	1.0070	1.0086	1.0100	150	1.0366	1.0469	1.0582	1.0687
75	1.0060	1.0076	1.0092	1.0107					

*This table is based on Tables 25 and 7 of "Petroleum Measurement Tables" published by the American Society for Testing and Materials, 1916 Race St., Philadelphia, PA, 19103. Values given are reciprocals of the multiplier values in Tables 25 and 7 as

$$C_t = \frac{1}{\text{multiplier for volume reduction to } 60°F}$$

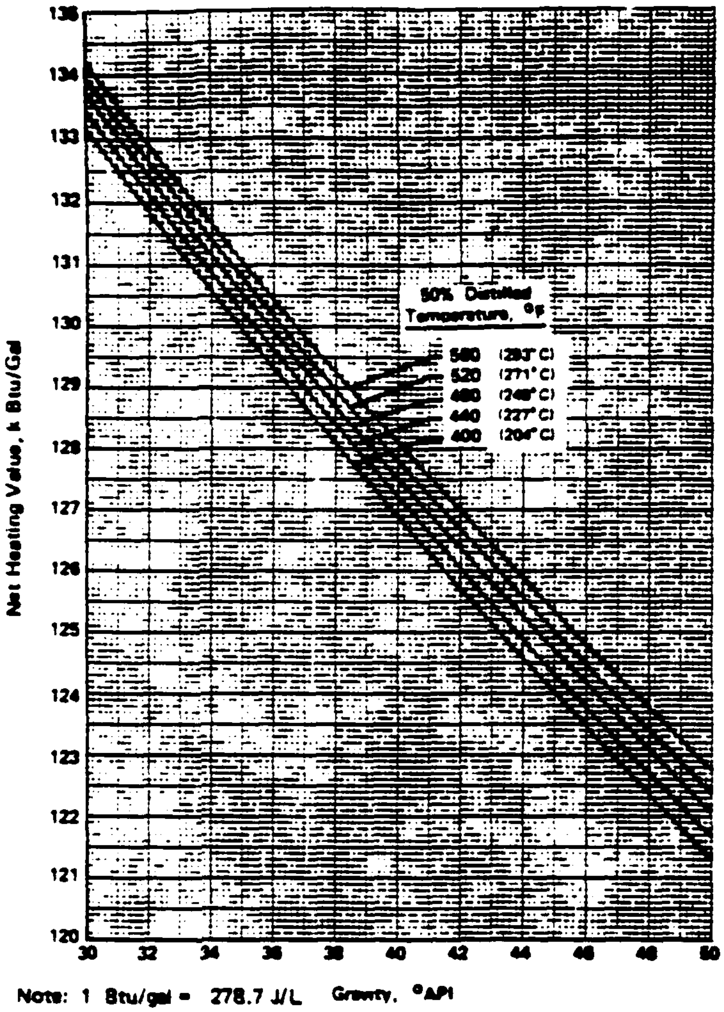
TABLE 1A—C_t—FUEL TEMPERATURE CORRECTION FACTOR* (SI UNITS)

ASTM Group Number	Specific Gravity Range	API Gravity Range, °API
1	0.8499–0.9659	15.0–34.9
2	0.7754–0.8498	35.0–50.9
3	0.7239–0.7753	51.0–63.9
4	0.6723–0.7238	64.0–78.9

Fuel Temp., °C	C_t Group 1	C_t Group 2	C_t Group 3	C_t Group 4	Fuel Temp., °C	C_t Group 1	C_t Group 2	C_t Group 3	C_t Group 4
−15	0.9784	0.9734	0.9679	0.9629	25	1.0068	1.0085	1.0104	1.0121
−14	0.9791	0.9742	0.9689	0.9641	26	1.0075	1.0095	1.0115	1.0134
−13	0.9798	0.9751	0.9699	0.9653	27	1.0083	1.0104	1.0127	1.0147
−12	0.9805	0.9760	0.9710	0.9664	28	1.0090	1.0113	1.0138	1.0161
−11	0.9812	0.9768	0.9720	0.9676	29	1.0097	1.0122	1.0150	1.0174
−10	0.9818	0.9777	0.9730	0.9688	30	1.0104	1.0131	1.0161	1.0187
−9	0.9826	0.9785	0.9741	0.9700	31	1.0112	1.0141	1.0172	1.0201
−8	0.9833	0.9794	0.9751	0.9712	32	1.0119	1.0150	1.0184	1.0214
−7	0.9840	0.9803	0.9761	0.9724	33	1.0126	1.0159	1.0195	1.0228
−6	0.9847	0.9811	0.9772	0.9736	34	1.0133	1.0168	1.0207	1.0241
−5	0.9854	0.9819	0.9782	0.9748	35	1.0141	1.0177	1.0218	1.0254
−4	0.9861	0.9828	0.9792	0.9760	36	1.0148	1.0187	1.0229	1.0268
−3	0.9868	0.9837	0.9803	0.9771	37	1.0155	1.0196	1.0241	1.0281
−2	0.9875	0.9845	0.9813	0.9783	38	1.0162	1.0205	1.0252	1.0295
−1	0.9882	0.9854	0.9823	0.9795	39	1.0170	1.0214	1.0264	1.0308
0	0.9889	0.9863	0.9834	0.9807	40	1.0177	1.0224	1.0275	1.0322
1	0.9896	0.9871	0.9844	0.9820	41	1.0184	1.0233	1.0287	1.0336
2	0.9903	0.9880	0.9854	0.9832	42	1.0191	1.0243	1.0299	1.0350
3	0.9910	0.9889	0.9865	0.9844	43	1.0199	1.0252	1.0310	1.0364
4	0.9918	0.9898	0.9876	0.9856	44	1.0206	1.0262	1.0322	1.0378
5	0.9925	0.9907	0.9886	0.9868	45	1.0213	1.0271	1.0334	1.0392
6	0.9932	0.9916	0.9897	0.9881	46	1.0221	1.0281	1.0346	1.0406
7	0.9939	0.9924	0.9908	0.9893	47	1.0228	1.0290	1.0358	1.0419
8	0.9946	0.9933	0.9918	0.9906	48	1.0235	1.0300	1.0370	1.0433
9	0.9953	0.9942	0.9929	0.9918	49	1.0243	1.0309	1.0381	1.0447
10	0.9960	0.9950	0.9939	0.9930	50	1.0250	1.0318	1.0393	1.0461
11	0.9968	0.9960	0.9950	0.9943	51	1.0258	1.0328	1.0405	1.0475
12	0.9975	0.9969	0.9961	0.9956	52	1.0265	1.0338	1.0417	1.0490
13	0.9982	0.9978	0.9972	0.9968	53	1.0272	1.0347	1.0429	1.0504
14	0.9989	0.9986	0.9983	0.9981	54	1.0280	1.0357	1.0441	1.0519
15	0.9996	0.9995	0.9994	0.9993	55	1.0287	1.0366	1.0453	1.0533
16	1.0003	1.0004	1.0005	1.0005	56	1.0294	1.0376	1.0465	1.0548
17	1.0010	1.0013	1.0016	1.0018	57	1.0302	1.0385	1.0477	1.0562
18	1.0018	1.0022	1.0027	1.0031	58	1.0309	1.0395	1.0489	1.0577
19	1.0025	1.0031	1.0038	1.0044	59	1.0316	1.0404	1.0501	1.0592
20	1.0032	1.0040	1.0049	1.0056	60	1.0324	1.0414	1.0513	1.0606
21	1.0039	1.0049	1.0060	1.0069	61	1.0332	1.0424	1.0526	1.0621
22	1.0046	1.0058	1.0071	1.0082	62	1.0339	1.0434	1.0538	1.0635
23	1.0054	1.0067	1.0082	1.0095	63	1.0347	1.0444	1.0550	1.0650
24	1.0061	1.0076	1.0093	1.0108	64	1.0354	1.0454	1.0562	1.0664

*This table is based on Tables 25 and 7 of "Petroleum Measurement Tables" published by the American Society for Testing and Materials, 1916 Race St., Philadelphia, PA, 19103. Values given are reciprocals of the multiplier values as:

$$C_t = \frac{1}{\text{multiplier for volume reduction to } 15.6\,°C}$$



Note: 1 Btu/gal = 278.7 J/L

k Btu/gal = 1000 Btu/gal

FIG. 1—VOLUMETRIC NET HEAT CONTENT OF DIESEL FUELS

11.2.2 Correction Formula

$$FE_c = FE_o \cdot C_1 \cdot C_2 \cdot C_3 \cdot C_4$$

11.2.3 Correction Factors

$C_1 = 1 + 0.0025\ (15.6 - T_A)$
$C_2 = 1.0$ Urban Cycle
$= 1.0 + 0.0021\ (P - 98)$ Suburban Cycle
$= 1.0 + 0.0025\ (P - 98)$ 89 km/h Interstate Cycle
$= 1.0 + 0.0043\ (P - 98)$ 113 km/h Interstate Cycle
$C_3 = 1.0 - 0.8\ (0.737 - G_s)$

- C_4 is derived from Table 1A based on gravity of fuel at 15.6°C and T_f or from the following analytical equation:

$$C_4 = a' + b'T_f + c'T_f^2$$

where the coefficients a', b', c' are:

ASTM Fuel Group

Coefficient	1	2	3	4
a'	9.8892 (10)$^{-1}$	9.8626 (10)$^{-1}$	9.8333 (10)$^{-1}$	9.8067 (10)$^{-1}$
b'	7.0693 (10)$^{-4}$	8.6875 (10)$^{-4}$	1.0487 (10)$^{-3}$	1.2090 (10)$^{-3}$
c'	3.0370 (10)$^{-7}$	8.4745 (10)$^{-7}$	1.4107 (10)$^{-6}$	2.0290 (10)$^{-6}$

11.3 **Fuel Economy Correction (Diesel)**

Note—The method for correcting observed fuel economy for vehicles with diesel engines has not been investigated to the same degree that it has for gasoline powered vehicles. However, the ambient temperature and barometric pressure corrections are primarily for changes in air density and its effect on aerodynamic drag. Hence, the correction factors for gasoline powered vehicles are recommended for use until additional data become available.

11.3.1 Definitions (see Section 11.2.1)

H = Volumetric heating value of test fuel (MJ/L).

11.3.2 Correction Formula

$$FE_c = FE_o \cdot C_1 \cdot C_2 \cdot C_3 \cdot C_4$$

11.3.3 Correction Factors

$C_1 = 1.0 + 0.0025\ (15.6 - T_A)$
$C_2 = 1.0$ Urban Cycle
$= 1.0 + 0.0021\ (P - 98)$ Suburban Cycle
$= 1.0 + 0.0025\ (P - 98)$ 89 km/h Interstate Cycle
$= 1.0 + 0.0043\ (P - 98)$ 113 km/h Interstate Cycle
$C_3 = K/H$
$K = 35.31$ MJ/L for ASTM 1D type fuel
$= 36.21$ MJ/L for ASTM 2D type fuel

H shall be determined from Fig. 1 by using the API gravity at 15.6°C and the 50% distillation point or from calorimeter tests.

- C_4 is derived from Table 1A based on gravity of fuel at 15.6°C and T_f or from the following analytical equation:

$$C_4 = a' + b'T_f + c'T_f^2$$

where the coefficients a', b', c' are:

ASTM Fuel Group

Coefficient	1	2
a'	9.8892 (10)$^{-1}$	9.8626 (10)$^{-1}$
b'	7.0693 (10)$^{-4}$	8.6875 (10)$^{-4}$
c'	3.0370 (10)$^{-7}$	8.4745 (10)$^{-7}$

12. Data Presentation

12.1 Test Vehicle Specifications and Preparation List
12.2 Fuel Economy Test—Data Form
12.3 Fuel Economy Test Data—Summary Sheet

ATTACHMENT 6

CRC COLD START AND WARMUP DRIVEABILITY PROCEDURE

TEST PROCEDURE AND DATA RECORDING

A. Record all necessary test information at the top of the data sheet.

B. Start engine per Owner's Manual Procedure. Record start time.

C. If engine fails to start after 15 seconds of cranking, stop cranking and depress accelerator pedal to the floor once and release. Begin cranking and record total cranking time until engine starts.

D. Record idle quality in "Neutral" or "Park" immediately after start; foot should be removed from accelerator pedal.

E. If engine stalls, repeat Steps B and C. Record number of stalls and starting time of required restarts.

F. Allow engine to idle 15 seconds. Apply brakes (right foot), shift to normal drive range, and record idle quality. If engine stalls, restart immediately. Do not record restart time. Record number of stalls. Idle 5 seconds in "Drive".

This completes the start-up portion of the procedure. Note that space on the data sheet has only been provided for two restart times at any idle condition. If three stalls occur at any condition, record the three stalls, restart (without recording time) and proceed to the next scheduled condition.

G. After 5 seconds in "Drive" (Step F), make a light throttle (Lt. th) acceleration from 0-25 mph at constant throttle opening beginning at the predetermined manifold vacuum.* Cruise at 25 mph. At the 0.2 mile marker open throttle to the detent position and accelerate from 25 to 35 mph at constant throttle in high gear. Decelerate to a stop, and at the 0.3 mile marker make a WOT acceleration from 0 to 35 mph. Decelerate to 10 mph and at mile marker 0.4 accelerate at light throttle from 10 to 25 mph. Definitions of light throttle, detent, and WOT accelerations are attached.

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* Marked on vacuum gauge.

H. During the above maneuvers, observe and record the severity of any of the following malfunctions (see attached definitions):

1. Hesitation
2. Stumble
3. Surge
4. Stall
5. Backfire

Record maneuvering stalls on the data sheet in the appropriate column: accelerating or decelerating. In addition, measure and record the time required to accelerate from 0-25 on the 0-25 mph maneuver.

I. At the 0.5 mile marker, brake moderately to a stop on the right side of the roadway. Idle for 30 seconds in Drive. Record idle quality and number of stalls.

J. Perform Steps G, H, and I three times (1.5 miles). The mile marker for the beginning of each maneuver is indicated on the data sheet.

K. At mile marker 1.5, after completing the 30-second idle, make a crowd acceleration (constant predetermined vacuum) from 0-45 mph. Four-tenths of a mile is provided for this maneuver. Decelerate from 45 to 25 mph at the 1.9 mile marker, and open throttle to detent position and accelerate from 25 to 35 mph. At 2.0 miles decelerate to a stop and accelerate from 10 to 25 mph at light throttle. Rate and record malfunctions in these maneuvers as in Step H. Measure and record the time required to travel the first 0.3 miles of the 0-45 mph crowd maneuver. Idle 30 seconds in Drive as in Step I.

L. Perform Step K five times. Appropriate mile markers for the start of each maneuver are shown on the data sheet.

DEFINITIONS AND EXPLANATIONS

Test Run

Operation of a car throughout the prescribed sequence of operating conditions and/or maneuvers for a single test fuel.

Maneuver

A specified single vehicle operation or change of operating conditions (such as idle, acceleration or cruise) that constitutes one segment of the driveability driving schedule.

Cruise

Operation at a prescribed constant vehicle speed with a fixed throttle position on a level road.

Wide Open Throttle (WOT) Acceleration

"Floorboard" acceleration through the gears from prescribed starting speed. Rate at which throttle is depressed is to be as fast as possible without producing tire squeal or appreciable slippage.

Part-Throttle (PT) Acceleration

An acceleration made an any defined throttle position, or consistent change in throttle position, less than WOT. Several PT accelerations are used. They are:

1. Light Throttle (Lt. Th) - All light throttle accelerations are begun by opening the throttle to an initial manifold vacuum and maintaining constant throttle position throughout the remainder of the acceleration. The vacuum selected is one inch Hg greater than the initial power cut-in vacuum obtained from carburetor flow curves. However, if a 0-25 mph light throttle maneuver (car warmed up) cannot be completed in 0.1 mile, vacuum is decreased in steps of one inch Hg until the 0-25 maneuver can be completed in 0.1 mile. The selected vacuum is posted in each car.

2. Crowd - An acceleration made at a constant intake manifold vacuum. To maintain constant vacuum, the throttle opening must be continually increased with increasing engine speed. Crowd accelerations are performed at the same vacuum prescribed for the light throttle acceleration.

3. Detent - All detent accelerations are begun by opening the throttle to the downshift position as indicated by transmission shift characteristic curves. Manifold vacuum corresponding to this point at 25 mph is posted in each car. Constant throttle position is maintained to 35 mph in this maneuver.

Malfunctions

1. Stall

   Any occasion during a test when the engine stops with the ignition on. Three types of stall, indicated by location on the data sheet, are:

   a. Stall; idle - Any stall experienced when the vehicle is not in motion, or when a maneuver is not being attempted.

   b. Stall; maneuvering - Any stall which occurs during a prescribed maneuver or attempt to maneuver.

   c. Stall; decelerating - Any stall which occurs while decelerating between maneuvers.

2. Idle Roughness

   An evaluation of the idle quality or degree of smoothness while the engine is idling.

3. Backfire

   An explosion in the induction or exhaust system.

4. Hesitation

   A temporary lack of vehicle response to opening of the throttle.

5. Stumble

   A short, sharp reduction in acceleration after the vehicle is in motion.

6. Surge

   Cyclic power fluctuations occurring during acceleration or cruise.

Malfunction Severity Ratings

The number of stalls encountered during any maneuver are to be listed in the appropriate data sheet column. Each of the other malfunctions must be rated by severity and the letter designation entered on the data sheet. The following definitions of severity are to be applied in making such ratings.

1. Trace (T) - A level of malfunction severity that is just discernible to a test driver but not to most laymen.

2. Moderate (M) - A level of malfunction severity that is probably noticeable to the average layman.

3. Heavy (H) - A level of malfunction severity that is pronounced and obvious to both test driver and layman.

Enter a T, M, or H in the appropriate data block to indicate both the occurrence of the malfunction and its severity. More than one type of malfunction may be recorded on each line. If no malfunctions occur, enter a dash (-) to indicate that the maneuver was performed and operation was satisfactory during that maneuver.

DEMERIT CALCULATION SYSTEM

A numerical value for driveability during the CRC test is obtained by assigning demerits to operating malfunctions as shown in Table IV. Depending upon the type of malfunction, demerits are assigned in various ways. Demerits for poor starting are obtained by subtracting two seconds from the measured starting time. The number of stalls which occur during idle as well as during driving maneuvers are counted separately and assigned demerits as shown in Table IV. The multiplying factors of 8 and 32 for idle and maneuvering stalls, respectively, account for the fact that stalls are very undesirable, especially during car maneuvers.

Other malfunctions, such as hesitation, stumble, surge, idle roughness, and backfire, are rated subjectively by the driver on a scale of trace, moderate, or heavy. For these malfunctions, a certain number of demerits is assigned to each of the subjective ratings. However, since all malfunctions are not of equal importance, the demerits are multiplied by the weighting factors shown in Table IV to yield weighted demerits.

Finally, weighted demerits, demerits for stalls, and demerits for poor starting are summed to obtain total weighted demerits (TWD), which are used as an indication of driveability during the test. As driveability deteriorates, TWD increases.

ATTACHMENT 6

METHOD FOR CALCULATING TOTAL WEIGHTED DEMERITS (TWD)

Demerits for Poor Starting:

Demerits = Starting Time(s) - 2

Demerits for Stalls:

Demerits = (No. of Idle Stalls) x 8 + (No. of Maneuvering Stalls) x 32

Demerits for Malfunctions Rated Subjectively:

Demerits for Subjective Ratings

Trace	=	1
Moderate	=	2
Heavy	=	4

Weighting Factors for Each Malfunction

Idle Roughness	=	1
Surge	=	4
Backfire, Stumble, Hesitation	=	6

Weighted Demerits = Demerits x Weighting Factor

Calculation:

Total Weighted Demerits = Weighted Demerits + Demerits for Stalls + Demerits for Poor Starting

Note: When more than one malfunction occurs in a driving maneuver, only the malfunction giving the highest weighted demerits is counted.

APPENDIX E

RAW DATA

Table E-1

VEHICLE A

INDIVIDUAL RESULTS

	FBRU RON				
	80	84	87	91	97
Driveability Demerits	4	8	0	1	0
<u>SAE Fuel Economy, MPG</u>					
Urban Cycle	21.05	22.27	22.37	24.18	22.42
	22.21	21.81	22.27	22.87	22.32
	22.30	21.81	22.37	23.23	22.34
	-	-	-	21.18	-
Suburban Cycle	32.51	33.15	33.29	32.72	30.55
	32.48	33.95	33.40	32.17	31.74
	32.62	33.70	31.40	32.74	33.22
	-	-	31.99	33.53	-
Interstate 55 MPH	36.61	35.96	35.19	40.09	36.61
	36.79	36.26	36.56	37.30	35.47
	36.78	36.84	36.98	39.50	34.06
				37.60	-
<u>WOT Acceleration</u>					
0-30 MPH, sec.	5.10	4.34	4.64	4.65	4.30
	4.86	4.32	4.35	4.84	4.46
	4.77	4.43	4.50	4.57	4.30
	4.98	4.69	4.51	4.57	4.62
	4.61	4.71	4.52	4.37	4.28
	4.91	4.55	4.44	4.54	4.64
0-50 MPH, sec.	10.02	9.04	9.39	9.46	9.10
	9.85	9.15	8.93	9.89	9.44
	9.60	9.07	9.41	9.34	9.21
	9.92	9.49	9.37	9.47	9.61
	9.75	9.38	9.30	9.04	9.01
	9.47	9.28	9.41	9.51	9.72
0-60 MPH, sec.	13.02	12.06	12.44	12.45	12.16
	13.04	12.26	12.75	12.97	12.63
	12.75	11.97	12.47	12.33	12.13
	13.15	12.48	12.47	12.57	12.67
	12.82	12.43	12.26	12.03	11.97
	12.68	12.27	12.50	12.61	12.95

Table E-1 (cont.)

VEHICLE A

INDIVIDUAL RESULTS

	FBRU RON				
	80	84	87	91	97
40-60 MPH, sec.	8.18	7.87	7.29	7.28	7.29
	8.31	8.05	7.57	7.66	7.97
	8.28	7.95	8.05	7.09	7.42
	8.31	7.94	7.63	7.09	7.70
	8.52	7.76	8.15	7.12	7.23
	8.52	8.06	-	7.57	7.92
0-5 Seconds, feet	109	132	128	129	140
	121	137	120	121	134
	119	132	135	130	138
	117	125	134	132	130
	115	121	134	138	140
	127	127	133	135	127
1/4 Mile, sec.	19.88	18.93	19.22	19.21	18.89
	19.68	19.03	19.43	19.58	19.26
	19.50	18.98	19.15	19.12	18.97
	18.56	19.33	19.20	19.24	19.34
	19.62	19.27	19.10	18.88	18.89
	19.38	19.16	19.25	19.27	19.61
1/4 Mile, MPH	73.02	74.39	73.72	73.77	74.27
	72.89	73.56	73.07	72.72	72.52
	73.64	74.40	73.35	73.98	73.75
	72.08	73.49	72.81	73.31	73.05
	73.08	73.68	74.05	74.56	73.87
	73.57	73.90	72.62	73.00	72.38
<u>Maximum Throttle Acceleration</u>					
40-60 MPH, sec.	12.46	11.90	10.89	10.18	10.39
	13.01	11.93	11.85	10.76	11.31
	12.35	11.72	10.63	10.30	10.36
	12.58	11.87	12.22	11.03	11.05
	12.26	11.59	10.83	10.13	10.37
	12.27	11.67	12.14	11.38	11.22

Table E-2

VEHICLE B

INDIVIDUAL RESULTS

	FBRU RON			
	87	91	97	100
Driveability Demerit	0	0	0	0
SAE Fuel Economy, MPG				
Urban Cycle	21.79	21.63	20.96	20.53
Suburban Cycle	28.53	28.52	27.90	26.54
Interstate 55 MPH	30.27	30.33	29.55	28.05
WOT Acceleration				
0-30 MPH, sec.	3.4 3.5	3.2 3.3	3.0 3.1	3.0 3.0
0-50 MPH, sec.	7.5 7.8	7.2 7.2	6.8 7.0	6.6 6.6
0-60 MPH, sec.	10.8 11.3	10.4 10.5	9.5 10.0	9.4 9.5
40-60 MPH, sec.	5.8 6.0	5.3 5.5	5.0 5.2	4.8 5.0
0-5 Seconds, MPH	40 39	41 41	43 42	44 44

Table E-3

VEHICLE C

INDIVIDUAL RESULTS

	FBRU RON			
	87	91	97	100
Driveability Demerits	0	0	0	0
SAE Fuel Economy, MPG				
Urban Cycle	14.71	15.87	15.12	14.99
Suburban Cycle	19.67	19.43	20.29	20.41
Interstate 55 MPH	25.44	24.18	25.19	25.18
WOT Acceleration				
0-30 MPH, sec.	4.0 4.6	3.6 4.2	3.0 3.2	2.9 3.0
0-50 MPH, sec.	11.0 12.0	9.7 10.5	6.4 7.0	6.3 6.5
0-60 MPH, sec.	15.3 16.5	12.6 14.2	9.2 9.9	9.0 9.2
40-60 MPH, sec.	9.0 10.1	7.0 7.8	4.6 4.9	4.5 4.6
0-5 Seconds, MPH	33 31	37 33	43 42	44 43

Table E-4

VEHICLE D

INDIVIDUAL RESULTS

	FBRU RON			
	87	91	97	100
Driveability Demerits	6	7	7	8
SAE Fuel Economy, MPG				
Urban Cycle	18.2	18.7	18.7	18.7
Suburban Cycle	29.2	29.2	29.5	29.2
Interstate 55 MPH	32.3	33.2	32.6	32.9
Interstate 70 MPH	27.1	27.9	27.9	27.5
WOT Acceleration				
0-30 MPH, sec.	4.5	4.5	4.6	4.3
	4.7	4.6	4.6	4.4
	4.5	4.6	4.8	4.4
	4.6	4.5	4.6	4.4
	4.6	4.6	4.7	4.5
	4.5	4.4	4.8	4.5
0-50 MPH, sec.	9.0	8.9	9.1	8.9
	9.0	9.0	9.2	8.7
	9.0	9.0	9.2	8.8
	9.0	9.1	9.1	8.9
	9.0	8.9	9.2	9.0
	8.9	8.9	9.3	8.8
0-60 MPH, sec.	12.6	12.6	12.8	12.7
	12.7	12.6	12.8	12.2
	12.7	12.6	12.8	12.2
	12.8	12.7	12.8	12.6
	12.7	12.6	13.1	12.6
	12.7	12.5	13.1	12.3
40-60 MPH, sec.	7.4	7.3	7.2	7.0
0-5 Seconds, feet	127	128	125	132
	124	125	127	128
	127	124	120	131
	126	125	126	131
	126	124	124	126
	128	131	119	127

Table E-4 (cont.)

VEHICLE D

INDIVIDUAL RESULTS

	FBRU RON			
	87	91	97	100
0-5 Seconds, MPH	32.4	32.7	32.1	33.5
	31.9	32.2	32.3	33.2
	32.9	32.2	31.1	33.3
	32.2	32.3	31.7	33.5
	32.2	32.2	31.5	32.9
	32.7	33.0	30.8	32.9
1/4 Mile, sec.	19.0	19.0	19.2	19.0
	19.1	19.1	19.1	18.8
	19.1	19.1	19.3	18.8
	19.1	19.2	19.1	19.0
	19.1	19.1	19.3	19.1
	19.1	18.9	19.4	18.9
1/4 Mile, MPH	75.0	75.7	74.9	74.4
	75.0	75.0	74.6	76.8
	74.8	74.9	75.8	76.0
	74.8	74.9	74.7	74.3
	75.1	75.1	73.9	74.5
	74.6	75.6	74.7	75.6

Table E-5

VEHICLE E

INDIVIDUAL RESULTS

	FBRU RON				
	83	87	91	97	100
Driveability Demerits	20	-	-	-	20
SAE Fuel Economy, MPG					
Urban Cycle	17.9	-	-	-	17.6
	18.4	-	-	-	18.1
	18.6	-	-	-	18.3
Suburban Cycle	31.3	-	-	-	31.4
	31.4	-	-	-	31.6
	32.0	-	-	-	31.7
Interstate 55 MPH	34.9	-	-	-	34.3
	35.0	-	-	-	34.5
	35.0	-	-	-	34.8
Interstate 70 MPH	30.5	-	-	-	30.2
	30.6	-	-	-	30.9
	30.7	-	-	-	31.1
WOT Acceleration					
0-30 MPH, sec.	4.32	4.23	4.08	4.20	4.17
	4.47	4.29	4.17	4.08	4.17
	4.32	4.29	4.29	4.20	4.17
	4.50	4.35	4.23	4.17	4.26
	4.44	4.32	4.20	4.20	4.17
0-50 MPH, sec.	8.94	8.91	8.61	8.76	8.67
	9.27	8.97	8.76	8.64	8.58
	9.03	8.94	8.94	8.70	8.79
	9.18	8.91	8.79	8.67	8.97
	9.12	8.91	8.79	8.79	8.91
0-60 MPH, sec.	12.24	12.21	11.97	12.21	12.18
	12.60	12.30	12.18	12.09	12.09
	12.48	12.30	12.21	12.12	12.18
	12.57	12.33	12.15	12.06	12.30
	12.51	12.24	12.12	12.12	12.33
40-60 MPH, sec.	6.06	6.03	6.03	6.12	6.12
	6.21	6.06	6.09	6.06	6.09
	6.27	6.09	6.00	6.06	6.15
	6.12	6.06	6.03	6.03	6.15
	6.15	6.03	6.03	6.00	6.27

Table E-5 (cont.)

VEHICLE E

INDIVIDUAL RESULTS

	FBRU RON				
	83	87	91	97	100
0-5 Seconds, feet	142	144	148	145	146
	139	143	144	149	148
	144	142	144	147	147
	139	142	146	146	143
	141	143	145	144	146
0-5 Seconds, MPH	33.57	33.84	35.02	34.41	34.45
	32.88	33.73	34.32	34.94	33.78
	33.65	33.89	33.68	34.59	34.23
	32.64	33.34	34.10	34.55	33.89
	33.13	33.76	34.05	34.30	34.61
<u>Maximum Throttle Acceleration</u>					
40-60 MPH, sec.	8.94	8.55	8.22	8.46	8.46
	8.73	8.58	8.31	8.40	8.52
	8.88	8.22	8.22	8.28	8.43
	8.73	8.22	8.10	8.25	8.46
	8.88	8.64	8.31	8.19	8.52
	8.73	-	-	-	-

Table E-6

VEHICLE F

INDIVIDUAL RESULTS

	FBRU RON 83	87	91	97	100
Driveability Demerits	102	38	10	-	10
<u>SAE Fuel Economy, MPG</u>					
Urban Cycle	15.9	16.3	16.8	16.2	17.0
	16.1	16.3	17.1	16.4	17.1
	16.2	16.5	17.2	16.4	17.2
Suburban Cycle	21.7	22.8	23.0	21.8	23.7
	23.1	23.0	23.1	22.0	24.0
	23.1	23.0	24.2	22.7	24.3
Interstate 55 MPH	29.2	28.6	29.7	28.1	28.8
	29.4	29.1	30.1	28.5	28.9
	29.4	29.4	30.2	28.6	29.1
Interstate 70 MPH	20.7	20.9	22.4	22.2	20.9
	21.5	22.0	23.8	22.3	21.4
	22.4	22.0	23.9	22.4	21.6
<u>WOT Acceleration</u>					
0-30 MPH, sec.	5.58	5.67	5.49	5.70	5.55
	5.58	5.55	5.58	5.61	5.43
	5.61	5.34	5.43	5.52	5.49
	5.46	5.49	5.31	5.70	5.52
	5.34	5.49	5.34	5.46	5.49
0-50 MPH, sec.	10.26	10.38	10.11	10.35	10.23
	10.32	10.17	10.35	10.17	10.17
	10.29	9.99	10.11	10.20	10.23
	10.11	10.23	9.96	10.47	10.29
	10.11	10.29	10.05	10.23	10.17
0-60 MPH, sec.	14.01	14.10	13.86	13.98	14.01
	14.16	13.89	14.07	13.98	13.89
	14.28	13.86	13.80	13.83	14.01
	14.10	14.04	13.74	14.16	14.04
	13.86	13.92	13.80	14.04	13.89
40-60 MPH, sec.	6.33	6.21	6.15	6.18	6.24
	6.45	6.24	6.36	6.24	6.30
	6.45	6.27	6.21	6.18	6.24
	6.48	6.30	6.30	6.27	6.33
	6.36	6.15	6.24	6.33	6.24

Table E-6 (cont.)

VEHICLE F

INDIVIDUAL RESULTS

	FBRU RON				
	83	87	91	97	100
0-5 Seconds, feet	113	113	118	112	117
	115	115	113	115	118
	115	117	118	115	117
	118	116	122	114	116
	120	115	118	119	116
0-5 Seconds, MPH	27.48	27.08	27.86	26.92	27.85
	27.61	27.63	27.67	27.67	27.86
	27.40	27.93	28.02	27.55	27.86
	28.09	27.87	28.50	27.11	27.68
	28.41	27.59	27.96	28.08	27.91
<u>Maximum Throttle Acceleration</u>					
40-60 MPH, sec.	14.91	16.74	16.23	13.56	17.25
	15.03	16.08	16.98	14.19	16.83
	15.42	15.72	15.60	16.26	16.47
	15.63	15.93	14.91	17.28	16.11
	15.36	17.19	14.43	15.06	17.31
40-60 MPH, sec. (retest)	13.50	15.03	14.16	14.37	14.58
	14.49	13.83	14.43	15.75	15.48
	14.49	13.92	13.23	15.03	15.00
	15.12	15.33	13.47	14.64	13.26
	14.25	14.88	13.02	14.79	15.12

Table E-7

VEHICLE G
INDIVIDUAL RESULTS

	FBRU RON				
	83	87	91	97	100
Driveability Demerits	108	11	-	-	17
SAE Fuel Economy, MPG					
Urban Cycle	-	16.4	-	-	15.2
	-	16.5	-	-	15.9
	-	16.5	-	-	16.1
Suburban Cycle	-	23.2	-	-	22.6
	-	23.2	-	-	22.9
	-	23.2	-	-	23.3
Interstate 55 MPH	-	26.6	-	-	26.2
	-	26.6	-	-	26.3
	-	26.9	-	-	26.5
Interstate 70 MPH	-	21.5	-	-	22.0
	-	21.6	-	-	22.2
	-	21.7	-	-	22.4
WOT Acceleration					
0-30 MPH, sec.	4.92	4.98	5.07	4.95	5.13
	4.86	4.89	4.95	4.98	5.04
	4.98	4.92	4.95	5.16	5.10
	4.89	4.83	4.95	5.01	5.01
	4.89	4.95	4.89	4.95	4.95
0-50 MPH, sec.	9.90	10.53	9.90	10.02	10.32
	9.84	10.26	9.93	10.11	10.17
	10.05	10.20	9.90	10.20	10.11
	9.90	10.14	10.38	10.05	10.02
	9.84	10.62	10.47	9.93	10.02
0-60 MPH, sec.	13.71	14.43	13.80	13.74	13.86
	13.71	14.43	13.68	13.86	14.01
	14.01	14.13	13.74	14.07	13.71
	13.83	14.13	14.37	13.83	13.74
	13.74	14.64	14.31	13.80	13.86
40-60 MPH, sec.	6.66	7.32	6.72	6.57	6.57
	6.75	7.32	6.57	6.81	6.81
	6.84	7.11	6.66	6.75	6.57
	6.75	7.11	7.29	6.66	6.60
	6.75	7.47	7.26	6.78	6.72

Table E-7 (cont.)

VEHICLE G

INDIVIDUAL RESULTS

	FBRU RON				
	83	87	91	97	100
0-5 Seconds, feet	124	123	119	123	116
	126	124	123	123	118
	123	125	121	115	119
	124	126	124	121	121
	123	121	125	124	122
0-5 Seconds, MPH	30.31	30.17	29.74	30.19	29.13
	30.57	30.47	30.39	30.05	29.65
	30.10	30.37	30.14	29.25	29.67
	30.64	30.97	30.31	29.80	29.91
	30.43	30.29	30.51	30.31	30.27
<u>Maximum Throttle Acceleration</u>					
40-60 MPH, sec.	12.36	11.67	11.79	11.97	11.91
	12.39	11.91	11.73	12.03	12.00
	12.33	11.73	11.79	11.91	11.82
	12.36	11.76	11.67	11.73	12.33
	12.57	11.88	11.82	11.82	11.91
<u>Part Throttle Acceleration</u>					
10-60 MPH, sec.	16.92	16.08	15.63	15.78	16.38
	16.77	15.93	15.75	15.72	15.97
	16.62	15.81	15.81	15.78	15.84
	16.98	15.66	15.81	15.39	15.27
	16.83	15.48	15.69	15.69	15.96

Table E-8

VEHICLE H

INDIVIDUAL RESULTS

	FBRU RON			
	82	87	91	97
Driveability Demerits	27	9	2	0
SAE Fuel Economy, MPG				
Urban Cycle	24.05	23.43	23.26	22.7
	25.48	24.39	23.07	23.3
	20.49	23.26	22.67	22.8
Suburban Cycle	24.61	22.30	26.33	27.00
	25.05	24.62	29.44	27.83
	26.89	24.29	28.40	27.16
Interstate 55 MPH	26.81	25.00	27.00	26.99
	26.50	27.80	26.97	21.98
	27.59	23.72	26.80	22.44
				25.91
WOT Acceleration				
0-30 MPH, sec.	5.84	5.27	5.03	4.92
	5.61	5.15	5.09	5.19
	5.42	5.29	5.13	4.94
	5.55	5.54	5.19	5.32
	5.91	5.23	5.24	5.19
	5.90	5.61	5.63	5.30
0-50 MPH, sec.	12.24	10.86	10.92	10.60
	12.65	11.72	11.36	11.43
	11.37	11.26	-	10.58
	12.69	12.45	11.83	11.65
	12.30	11.47	11.41	11.17
	13.55	13.69	12.29	12.18
0-60 MPH, sec.	16.42	15.18	15.20	14.96
	17.90	17.24	16.45	16.78
	15.76	15.09	15.10	14.89
	18.43	17.92	16.97	16.98
	16.86	15.60	16.07	15.43
	20.01	18.64	17.49	17.64
40-60 MPH, sec.	7.77	7.35	7.60	7.56
	9.38	9.23	8.64	8.92
	7.61	7.41	7.51	7.52
	9.93	9.61	8.98	9.00
	8.15	7.77	8.20	7.67
	11.13	10.13	9.06	9.56

Table E-8 (cont.)

VEHICLE H

INDIVIDUAL RESULTS

	FBRU RON			
	82	87	91	97
0-5 Seconds, feet	105	113	124	121
	113	122	122	115
	117	116	121	125
	114	116	120	116
	105	120	118	118
	109	112	105	119
1/4 Mile, sec.	21.3	20.5	20.4	20.3
	21.6	21.0	20.8	20.9
	20.8	20.6	20.4	20.2
	21.5	21.4	21.0	21.1
	21.4	20.9	20.7	20.6
	22.1	21.7	21.5	21.2
1/4 Mile, MPH	68.5	70.5	70.0	70.4
	65.3	65.8	66.5	66.6
	69.4	70.1	70.1	70.3
	64.7	65.3	66.1	66.3
	68.1	68.2	68.8	69.3
	63.3	64.3	66.0	65.5
Maximum Throttle Acceleration				
40-55 MPH, sec.	6.27	5.94	5.43	6.33
	7.65	7.58	6.67	6.52
	6.35	6.34	5.87	5.77
	7.48	8.23	7.00	6.72
	6.21	6.49	6.34	6.16
	7.93	8.17	7.43	7.04

Table E-9

VEHICLE I

INDIVIDUAL RESULTS

	FBRU RON				
	84	88	91	98	100
WOT Acceleration					
0-30 MPH, sec.	7.50	5.18	4.87	4.42	4.14
	7.35	5.71	5.17	4.13	3.99
	6.89	5.69	5.16	4.34	4.07
	6.76	5.33	4.97	4.50	3.93
	6.99	5.19	4.89	4.39	4.27
	7.10	5.59	4.84	4.28	4.00
0-50 MPH, sec.	17.43	15.13	10.77	8.28	8.26
	16.83	14.86	11.60	8.29	8.48
	16.74	15.99	12.02	8.52	8.12
	17.74	15.25	10.24	8.66	8.32
	18.83	15.29	10.38	8.57	8.10
	18.40	14.94	11.46	8.56	8.01
0-60 MPH, sec.	25.22	22.12	14.08	11.18	11.26
	24.46	22.15	15.08	11.19	11.35
	20.87	23.48	15.24	11.45	11.05
	24.99	22.28	13.32	11.70	11.18
	26.51	21.92	13.76	11.72	11.03
	25.77	22.79	14.46	11.65	11.12
40-60 MPH, sec.	16.61	13.50	11.33	6.21	6.36
	16.68	13.63	9.42	6.41	6.27
	21.66	14.22	10.24	6.53	6.43
	19.87	13.87	10.66	6.44	6.20
	17.99	14.16	10.94	6.56	6.39
	20.23	14.17	10.20	6.51	6.28
1/4 Mile, sec.	24.45	22.53	20.70	18.50	18.74
	23.70	22.89	21.37	18.76	18.20
	24.72	23.65	22.72	18.59	18.45
	24.01	23.36	22.27	18.84	19.00
	25.10	22.29	22.56	18.97	18.81
	24.15	22.67	21.86	18.67	18.67
1/4 Mile, MPH	58	62	66	80	81
	59	62	68	81	81
	59	62.5	66	81	81
	58	61	68	80	81
	58	62	67	81	81
	59	63	68	81	81

Table E-10

VEHICLE J

INDIVIDUAL RESULTS

WOT Acceleration	FBRU RON 79	85	91	93	95	97	98	100	104
0-30 MPH, sec.	4.72	4.57	4.36	4.23	4.14	4.23	4.14	4.27	4.18
	4.55	4.40	4.26	4.31	4.11	4.22	4.16	4.02	4.10
	4.49	4.45	4.28	4.17	4.17	4.31	4.10	4.05	4.09
	4.55	4.43	4.23	4.21	4.20	4.42	4.27	4.27	4.15
	4.68	4.48	4.21	4.19	4.14	4.24	4.18	4.14	4.09
	4.74	4.53	4.31	4.30	4.16	4.22	4.12	4.22	4.15
0-50 MPH, sec.	9.16	8.83	8.55	8.28	8.37	8.36	8.06	8.32	8.09
	9.07	8.84	8.40	8.32	8.22	8.23	8.16	8.14	7.99
	9.12	9.08	8.37	8.31	8.22	8.29	8.12	8.16	7.91
	9.14	9.09	8.40	8.41	8.26	8.52	8.28	8.33	8.00
	9.13	9.06	8.42	8.32	8.28	8.39	8.25	8.27	7.97
	9.23	9.17	8.51	8.44	8.25	8.51	8.22	8.44	8.11
0-60 MPH, sec.	12.54	12.09	11.44	11.18	11.30	11.02	10.87	11.09	10.78
	12.61	12.01	11.51	11.26	11.08	11.15	11.01	11.05	10.79
	12.51	12.44	11.37	11.79	10.96	11.14	10.97	10.89	10.66
	12.42	12.51	11.59	11.42	11.13	11.22	11.22	11.21	10.76
	12.40	12.46	11.37	11.33	11.31	11.23	11.02	11.20	10.81
	12.48	12.65	11.64	11.39	11.29	11.29	11.01	11.25	10.89
40-60 MPH, sec.	7.17	7.02	6.20	6.40	6.27	6.23	6.19	6.23	6.17
	7.11	6.92	6.34	6.24	6.17	6.22	6.26	6.29	6.23
	7.08	6.89	6.38	6.36	6.34	6.21	6.18	6.25	6.16
	7.07	7.00	6.40	6.22	6.28	6.33	6.22	6.11	6.13
	7.04	6.97	6.18	6.36	6.27	6.28	6.25	6.22	6.22
	7.14	6.91	6.30	6.33	6.22	6.20	6.20	6.22	6.18

Table E-10

VEHICLE J

INDIVIDUAL RESULTS

	FBRU RON								
	79	85	91	93	95	97	98	100	104
1/4 Mile, sec.	19.40	19.42	18.75	18.76	18.73	18.88	18.67	18.44	18.26
	19.35	19.62	18.91	18.65	18.88	18.71	18.59	18.33	18.32
	19.50	19.51	18.76	18.73	18.57	18.75	18.46	18.45	18.26
	19.59	19.23	19.20	18.67	18.68	18.62	18.52	18.49	18.18
	19.47	19.20	19.10	18.81	18.64	18.81	18.75	18.60	18.10
	19.33	19.37	18.96	18.82	18.69	18.58	18.87	18.57	18.08
1/4 Mile, MPH	74	74	76	78	78	78	79	78	80
	74	74	76	78	78	78	79	78	80
	74	74	76	78	78	78	79	78	80
	74	74	76	78	78	78	79	78	80
	74	74	76	78	78	78	79	79	80
	74	74	76	78	78	78	79	79	80

Table E-11

VEHICLE K

INDIVIDUAL RESULTS

	FBRU RON				
	84	86	93	97	100
WOT Acceleration					
0-30 MPH, sec.	5.35	5.14	4.89	4.87	4.55
	5.80	5.33	5.05	4.83	4.84
	5.54	5.46	4.93	5.10	4.86
	5.75	5.35	4.82	4.73	4.82
	5.69	5.47	5.03	4.80	4.83
	5.44	5.36	5.08	4.87	4.75
0-50 MPH, sec.	10.49	10.01	9.70	9.04	8.67
	10.89	10.20	9.34	8.92	8.81
	10.71	10.44	9.13	9.00	8.92
	10.87	10.29	9.34	8.86	8.90
	10.71	10.44	9.38	8.76	8.80
	10.72	10.33	9.32	8.78	8.86
0-60 MPH, sec.	14.41	13.57	12.91	11.95	11.66
	14.57	13.96	12.35	11.65	11.54
	14.38	14.02	12.36	11.85	11.93
	14.40	13.78	12.47	11.66	11.85
	14.36	13.85	12.52	11.52	11.79
	14.72	13.98	12.44	11.63	11.62
40-60 MPH, sec.	7.43	6.96	6.09	5.60	5.71
	7.40	7.01	5.88	5.87	5.64
	7.29	7.14	6.12	5.76	5.61
	7.44	7.27	5.90	5.84	5.84
	7.34	7.28	6.08	5.88	5.68
	7.53	6.98	6.15	5.70	5.69
1/4 Mile, sec.	20.41	20.28	19.77	19.69	19.10
	20.49	19.91	20.18	19.57	19.06
	20.93	20.32	19.83	19.33	19.02
	20.90	19.98	19.76	19.53	19.09
	20.67	20.22	19.76	19.37	18.99
	20.72	20.10	19.69	19.44	18.91
1/4 Mile, MPH	74	75	78	80	81
	74	75	79	80	81
	75	75	78	81	81
	74	74	78	81	81
	74	75	77	80	81
	74	74	77	80	81

Table E-12

VEHICLE L

INDIVIDUAL RESULTS

	FBRU RON				
WOT Acceleration	83	85	90	97	99
0-30 MPH, sec.	4.35	4.33	4.26	4.26	4.28
	4.47	4.32	4.31	4.29	4.28
	4.35	4.34	4.32	4.26	4.25
	4.39	4.32	4.40	4.29	4.31
	4.41	4.35	4.34	4.33	4.34
	4.46	4.28	4.34	4.33	4.29
0-50 MPH, sec.	8.69	8.58	8.43	8.26	8.36
	8.96	8.57	8.33	8.37	8.38
	8.83	8.63	8.37	8.38	8.32
	8.80	8.50	8.43	8.35	8.39
	8.89	8.46	8.54	8.39	8.38
	8.85	8.59	8.44	8.39	8.41
0-60 MPH, sec.	11.37	11.12	10.98	10.85	10.77
	11.66	11.00	10.96	10.96	10.86
	11.50	11.14	10.88	10.87	10.91
	11.52	11.05	10.93	10.79	10.89
	11.63	11.04	11.11	10.88	10.97
	11.44	11.12	10.98	10.92	10.92
40-60 MPH, sec.	5.94	5.95	5.90	5.90	5.98
	5.96	5.93	5.94	5.89	5.91
	6.06	5.89	5.92	5.91	5.94
	5.93	5.95	5.92	5.90	5.92
	5.98	6.04	5.93	5.87	5.93
	5.99	5.99	5.98	5.96	5.99
1/4 Mile, sec.	18.52	18.58	17.93	17.89	17.86
	18.58	18.54	18.25	18.02	18.04
	18.79	18.81	18.32	17.97	17.78
	18.66	18.68	18.10	17.79	17.77
	18.77	18.62	18.07	18.03	17.95
	18.69	18.74	18.19	17.94	17.89
1/4 Mile, MPH	79	80	81	82	82
	80	79	81	82	82
	79	80	81	82	82
	80	79	81	82	82
	80	79	81	82	82
	79	80	81	82	82

Table E-13

VEHICLE M

INDIVIDUAL RESULTS

	FBRU RON				
	81	84	90	95	98
WOT Acceleration					
0-30 MPH, sec.	4.56	4.29	4.26	4.21	4.21
	4.32	4.30	4.29	4.25	4.18
	4.45	4.33	4.30	4.24	4.25
	4.50	4.37	4.35	4.19	4.16
	4.52	4.28	4.33	4.27	4.25
	4.38	4.37	4.26	4.24	4.26
0-50 MPH, sec.	8.56	8.24	8.32	8.25	8.19
	8.42	8.34	8.38	8.18	8.20
	8.59	8.29	8.23	8.19	8.21
	8.60	8.32	8.37	8.29	8.23
	8.61	8.28	8.32	8.25	8.28
	8.48	8.35	8.24	8.27	8.25
0-60 MPH, sec.	11.45	11.12	11.04	10.89	10.93
	11.22	11.06	11.17	10.96	11.04
	11.37	11.19	11.07	10.83	11.02
	11.48	11.12	11.16	11.01	10.87
	11.39	11.07	11.25	11.02	10.89
	11.18	11.15	10.98	11.10	10.87
40-60 MPH, sec.	5.98	5.85	5.88	5.72	5.60
	5.90	5.89	5.74	5.82	5.64
	5.83	5.86	5.84	5.80	5.63
	5.89	5.87	5.86	5.65	5.54
	5.85	5.82	5.81	5.69	5.66
	5.95	5.79	5.82	5.65	5.64
1/4 Mile, sec.	18.16	18.19	18.15	18.04	18.01
	18.21	18.25	18.39	18.13	18.11
	18.48	18.15	18.20	18.19	17.98
	18.54	18.27	18.32	18.03	18.06
	18.12	18.18	18.18	18.10	17.95
	18.19	18.28	18.22	18.00	18.03
1/4 Mile, MPH	77	78	78	79	80
	77	78	79	79	80
	78	78	78	80	80
	78	78	79	80	80
	77	78	78	80	80
	77	78	79	80	80

Table E-14

VEHICLE N

INDIVIDUAL RESULTS

	FBRU RON 82	84	90	96	98
WOT Acceleration					
0-30 MPH, sec.	4.77	4.73	4.40	4.45	4.40
	4.69	4.80	4.43	4.47	4.46
	4.57	4.59	4.44	4.39	4.44
	4.82	4.73	4.38	4.30	4.42
	4.78	4.71	4.47	4.27	4.45
	4.67	4.77	4.40	4.30	4.35
0-50 MPH, sec.	9.92	9.86	9.37	9.29	9.31
	9.95	10.00	9.44	9.33	9.42
	9.90	9.86	9.50	9.19	9.29
	9.99	9.96	9.40	9.15	9.37
	10.02	9.90	9.51	9.10	9.36
	10.05	9.99	9.45	9.23	9.28
0-60 MPH, sec.	12.85	12.80	11.95	11.99	11.87
	12.89	12.85	12.08	12.01	12.00
	12.82	12.65	12.06	11.87	11.89
	12.88	12.79	11.97	11.92	11.95
	12.93	12.76	12.04	11.82	12.03
	12.85	12.85	12.00	11.94	11.99
40-60 MPH, sec.	5.58	5.60	5.37	5.22	5.24
	5.57	5.53	5.35	5.27	5.23
	5.62	5.53	5.28	5.19	5.27
	5.53	5.54	5.34	5.25	5.32
	5.61	5.59	5.31	5.24	5.28
	5.57	5.55	5.29	5.20	5.30
1/4 Mile, sec.	21.45	21.52	21.42	21.00	21.19
	21.43	21.29	21.19	20.92	20.98
	21.39	21.38	21.21	20.88	21.08
	21.49	21.47	21.40	20.79	21.20
	21.42	21.35	21.29	20.91	21.17
	21.52	21.40	21.33	20.85	21.10
1/4 Mile, MPH	68	68	69	69	70
	67	68	69	69	70
	67	68	69	70	70
	68	69	69	70	70
	67	68	69	69	70
	68	68	69	70	70